The Glasgow Naturalist

Volume 24 Part 1 2002

Journal of
THE GLASGOW NATURAL HISTORY SOCIETY

GLASGOW NATURAL HISTORY SOCIETY
(formerly The Andersonian Naturalists of Glasgow)

The object of the Society is the encouragement of the study of natural history in all its branches, by meeting for reading and discussing papers and exhibiting specimens and by excursions for field work. The Glasgow Natural History Society meets at least once a month except during July and August, in the University of Glasgow, the Glasgow Art Gallery and Museum, or Hillhead Library.

The present rates of subscription per annum are: for Ordinary Members, £17: Family Members, £3 extra; Junior Members (under 21) £8; School Members, £1. Payment by Direct Debit is encouraged.

Further information regarding the Society's activities and membership application forms are obtainable from the General Secretary, c/o Natural History Department, Museum & Art Gallery, Kelvingrove, Glasgow G3 8AG.

The Glasgow Natural History Society website is http://tftw.freeuk.com/gnhs/ , which also contains details of the Glasgow Naturalist.

The Glasgow Naturalist

The Glasgow Naturalist is published by the Glasgow Natural History Society. ISSN 0373-241X. Price £14.00 plus £1.50 p.&p. UK; £3.00 overseas. The Glasgow Naturalist is free to members.

The Glasgow Naturalist is edited by Azra Meadows and Peter Meadows, Graham Kerr Building, University of Glasgow G12 8QQ (Tel: 0141 330 6622, Email: gbza31@udcf.gla.ac.uk) with the help of J.R. Downie R.H. Dobson, A. McG. Stirling,and T.N. Tait.

Contributions are invited, especially when they bear on the natural history of Scotland.

Full details of how to contribute articles or short notes are given at the end of the volume. A limited number of advertisements can be accepted and enquiries should be sent to the Editors.

This publication is included in the abstracting and indexing coverage of the Bioscience Information Service of Biological Abstracts and the Botanical Society of the British Isles Abstracts.

The following back numbers are available for purchase in their separate parts:

Vols.II - VII (1890-1918); Vols. XIII - XXIII (1937-1999).

Of the earlier Journals the only parts available are:

Proceedings and Transactions of the Natural History Society of Glasgow Vol. II pt. 2; Vol. VI pt. 1; Vol. VII, pt. 3; Vol. VIII, pts. 1 & 2.

Enquiries regarding prices of and orders for any of the above, or for reprints or photocopies, should be addressed to the Librarian: Mrs Joan Chapman, 121 Randolph Road, Jordanhill, Glasgow G11 7DS.

Publications of Glasgow Natural History Society

Alien Species: friends or foes? Edited by J.R.Downie (2001). Proceedings of the GNHS 150th Anniversary Conference. Price £10.00 plus p & p £1.50.

Bound copies of the following may be obtained from the Librarian at the address above and at the prices shown:

The Flora of the Clyde Area (Original printing). J.R. LEE, Price £11.00 to members of GNHS and to the book trade; £13.50 to others (p. & p. £1.00 extra). This is still the only work of its type and is in diminishing supply. A few unbound copies are available: £5 (p.&p. £1 extra).

The Flora of Ailsa Craig. B. ZONFRILLO, 1994. Price £2.50 plus p.& p.50p.

The Natural History of the Muck Islands, N. Ebudes:

1. Introduction and Vegetation with a List of Vascular Plants. R.H. DOBSON & R.M. DOBSON, 1985. Price £1.00 plus p. & p. 50p.
3. Seabirds and Wildfowl. R.H. DOBSON & R.M. DOBSON, 1986. Price £1.00 plus p. & p. 50p.
5. Landbirds. R.H. DOBSON, 1988. Price £1.00 plus p. & p. 50p.

The following bound reprints from the *Glasgow Naturalist* may be obtained from the librarian at the above address and at the prices shown.

Additions to the Flora of the Clyde Area. John R. Lee (1953). £1 (p.&p. 50p).

Archives

The Society's archives are in the hands of the City Archivist, Mr Andrew Jackson, and stored at the Mitchell Library, Ref. No. TD 1408. To access, telephone Mr Jackson 0141-287-2907 or Robert Urquhart 287-2914.

The Glasgow Naturalist
Volume 24 Part 1 2002

CONTENTS

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 1-14.

Presidential Address, 26th February, 2002

LONG-TERM NATURAL HISTORY
SOME ASPECTS OF THE ENVIRONMENT AND LIVING THINGS

R.Gray
President
Glasgow Natural History Society
6, Prince Albert Road,Glasgow G12 9JX

Our new president, Roger Downie, in his earlier guise as Editor of the most recent issue of 'The Glasgow Naturalist' commented in his editorial that the Society rarely engages with major modern advances in the biological sciences and he posed the question: 'Is our Society taking too narrow a view of what natural history is?' Whilst not proposing to answer this question in full I propose to take a brief look at some controversial aspects of the subject that draws us all to this Society.

Natural history has been defined as the study of natural phenomena ....including inanimate phenomena, such as rocks, soils and climate, but commonly confined to living things, animals and plants in the wild. (Fitter, 1967). Ecology is defined as the study of the relationship between plants and animals and their environment. (Haeckel, biologist and philosopher, 1866).

I should like to look at the connection between these two in the light of present day knowledge. This means that I shall look at the inter-relationships between the environment, plants (mainly trees) and animals (mainly birds and mammals) with particular but not exclusive reference to a Scottish context.

My interest in atmospheric CO_2 concentrations goes back to science lab experiments carried out to compare the O_2, CO_2 and N_2 volumes of inhaled air with exhaled air. The CO_2 content of inhaled air, 370 ppm, is so small as to be immeasurable in the context of an ordinary laboratory. There is some 40 times more water vapour in the air than CO_2 and it is a matter of common observation that cloudy evenings are warmer than clear evenings. So simple logic suggests that small variations in atmospheric CO_2 concentration will have little effect on global temperature. This is very much at odds with what we come across in the media.

EARTH'S CLIMATIC HISTORY: THE LAST 1,000,000 YEARS

Some 10 major ice ages have occurred over the past 1 million years (Figure 1). They recur at approximately 100,000 year intervals, persist for about 90,000 years, after which they have been followed by approximately 10,000 year interglacials. This periodicity has been attributed to the Croll - Milankovitch cycle (Figure 2), whereby regular changes in the distance of the earth from the sun affect the amount of solar radiation reaching the earth's surface (Farrow, 2001).

The glacial epoch about which we know the most is the most recent one which was at its peak about 20,000 years ago. Land plants suffered as the air's CO_2 content fell to about 180 ppm. This fall was caused by: a) the increased ability of colder water to hold more dissolved CO_2 and b) larger growth rates of phytoplankton caused by the amount of iron rich dust carried by the stronger winds of the period. Had the CO_2 concentration dropped much lower it is likely that several plant extinctions would have occurred, since many plants find it difficult to survive at CO_2 concentrations of the order of 50 to 100 ppm (Idso, 1989; Salisbury and Ross, 1978).

Large and rapid shifts in climate have been detected in Greenland and Antarctica from deep sediment cores, ice cores, lake sediments and pollen series, e.g. in Greenland rapid warming of some 7°C in a few decades was observed about 11,500 years ago (Dansgaard *et al.*, 1989; Johnsen *et al.*, 1992; Grootes *et al.*, 1993). Rapid warming, followed by periods of slower cooling and then rapid freezing are typical of interstadial events (as well as interglacials), of which about 20 occurred during the last glacial period. They lasted between 500 and 2000 years (Dansgaard *et al.*, 1993).

CO_2 AND TEMPERATURE: ICE CORE CORRELATIONS (Fischer *et al.*, 1999)

Evidence from Antarctic ice cores through the last three ice ages showed that the earth warmed up well before there was any increase in the air's CO_2 content. The relationship between temperature and CO_2 is just the reverse of what is assumed in all the climate model studies that warn of dramatic warming in response to the ongoing rise in the air's CO_2 content: temperature rises first, and then comes an increase in atmospheric CO_2.

NEARLY HALF A MILLION YEARS OF CLIMATE AND CO_2 (Petit *et al.*, 1999)

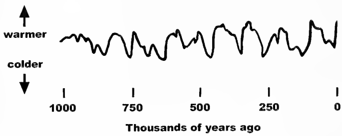
Petit *et al.*(1999) showed from the Vostok ice core going back 420,000 years that the 4 interglacials preceding the present one (the Holocene) were warmer by an average temperature of > 2°C. Hence the current interglacial is by far the coolest of the five most recent such periods (Figure 1).

Also "during glacial inceptio the CO_2 decrease lags the temperature decrease by several thousand years.". Since the current interglacial is by far the longest stable warm period of the past 420,000 years we are probably overdue for the next ice age.

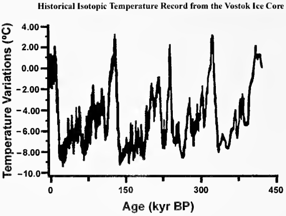
AIR TEMPERATURE OF THE PAST DECADE

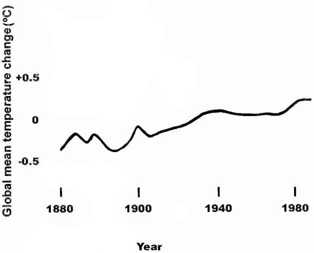
The air temperature of the last decade of the 20th century in terms of typical interglacial temperatures is clearly unusually cool, even if the temperature is warmer than it has been over the past 100 years (Figure 1). The air's CO_2 concentration today

Figure 1. Temperature change vs Time



Source: Budiansky, 1995





Source: Budiansky, 1995

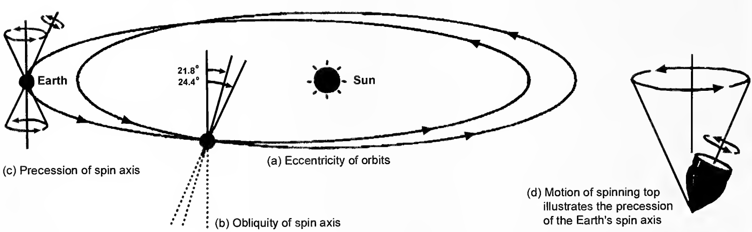
Regular patterns appear only on time scales of 100,000 years or more.

Top: Temperatures inferred from oxygen isotope fluctuations in ocean sediments.

Mid: From oxygen isotopes in the Vostok ice core.

Bottom: Global mean temperature from direct measurement.

Figure 2. Croll-Milankovitch Cycle



Earth's orbit varies in three ways: a), b) & c). These affect amount of radiation and so climate

Source: Lamb & Sington, 1999

stands at nearly 370 ppm whereas in the 4 prior interglacials it never rose above 290 ppm. So the higher temperatures of previous interglacials cannot be attributed to either CO_2 concentrations (they were lower) or to human interference (too few humans). So what is the most likely cause of climate change?

A 1000 YEAR HISTORY OF SUNSPOT NUMBERS (Rigozo *et al.*, 2001)

Both the Mediaeval and Modern maxima in sunspot numbers and solar radiation output are far above all other periods of the past thousand years. On this basis current temperatures are expected to be higher than at any other time during the past millennium. Studies of recent data from the European Space Agency's sun watching Soho satellite indicate a solar energy surge and a particularly big increase in UV light. This has coincided with a doubling in the strength of the sun's magnetic field, which blocks cloud-forming cosmic rays. Fewer clouds would mean that more heat reaches the Earth's surface, although it could be argued that warming of the Arctic Ocean has resulted in increased cloudiness at high northern latitudes. There is however no need to invoke variations in the air's CO_2 content as a cause of temperature variation.

ICE SHEETS IN THE NORTHERN HEMISPHERE (Figure 3)

When the ice of the last glaciation was at its greatest extent it reached south to the Chiltern hills, to the south and west of which was glacial outwash and tundra (Figure 4). The area south and west of Cornwall was dry land and may have been a refuge for trees such as the Strawberry tree (*Arbutus unedo*) which possibly migrated to southwest Ireland as the ice melted (Mitchell & Coombes, 1998). The ice of the last glaciation began to melt about 17,900 years ago (Huntley *et al.*, 1997) when the exposed land was colonised firstly by open ground taxa. These were then replaced by a dwarf shrub community that included *Juniperus, Salix* and *Betula nana* and occasional tree birches (Ramsay & Dickson, 1997). By about 14,600 years ago the ice had almost disappeared completely but by 12,900 year ago a substantial ice sheet, the Loch Lomond readvance, centred on Rannoch Moor had accumulated. About 11,200 years ago extremely rapid climatic warming caused the ice to melt finally thus allowing dwarf shrubs to migrate again into the area behind the melting ice. These were gradually followed by the major tree taxa.

After late-glacial times the first tree pioneers were the downy and silver birches (*Betula pubescens* and *B. pendula*) and Scots pine (*Pinus sylvestris*). The pollen record suggests that birch spread from the east across land now forming the bed of the North Sea. The genetic evidence is strong for the colonisation of Scotland by Scots pine by migration from north-central Europe mainly and from southern Europe (Ennos *et al.*, 1997). The expansion of pine from sheltered pockets in north west Scotland where it may have survived the last glacial period remains a matter of debate. In Scotland the tree birches were followed soon by hazel (Figure 5) then elm. Oak tends to arrive either at the same time as elm or slightly later (Ramsay & Dickson, 1997). Pollen analysis cannot distinguish between the two native oaks but the present distribution, with the sessile oak predominant in the north and west and at higher altitudes, suggest that the sessile preceded the common oak, which is found mainly in lowland areas and more in the south and east (Mitchell & Coombes, 1998). Also early to arrive were aspen and rowan.

The total complement of native trees was about 35, about 25 in Scotland (Table 1). Europe was unfortunate during the Ice Ages because the great mountain systems run from east to west. The flora and fauna were trapped between the northern ice and the mountain ice. The Mediterranean prevented access to Africa. In Canada and the northern USA, which experienced the same ice ages, the mountains run north to south.

Trees migrated southwards along mountains or valleys at their preferred climate, and afterwards migrated back again. Hence there is an immense wealth of species, broadleaved and coniferous, in North America. The National Park of the Appalachians, for example, possesses 131 native trees whereas the European figure is 85. Britain has two species of oak; the USA has 80. Britain was recolonised by species hardy enough to have survived on the European plains and sufficiently fast moving to migrate back in the 6000 years before the Channel was created.

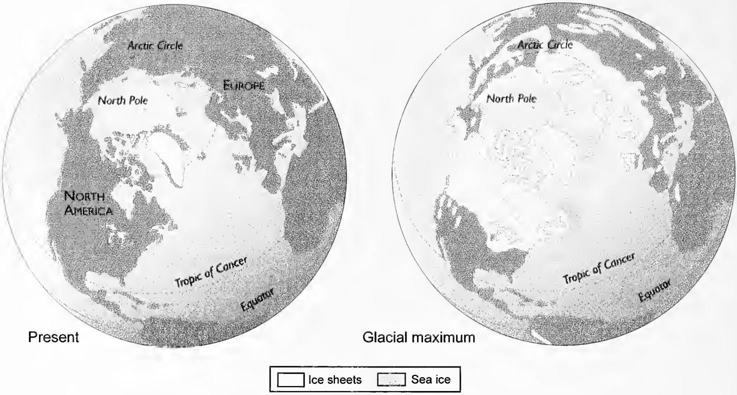
ISOCHRONE CONTOUR MAPS (FIGURES 6A AND 6B)

The maps show the history of the spread of some trees through these islands. During a warm early period the small-leaved lime (*Tilia cordata*) was dominant over large areas and the wych elm (*Ulmus glabra*) and bird cherry (*Prunus padus*) were other early arrivals. Ash (*Fraxinus excelsior*), field maple, yew and hawthorn arrived with time to spare, probably with wild cherry (*Prunus avium*) and crack willow. The land bridge was of chalk, and apart from holly and hornbeam, the last trees to cross it were those that thrive on chalk and are often now found wild only near chalk hills – the wild service tree, whitebeam, beech and, probably last, box. (Mitchell & Coombes, 1998.)

BRITAIN'S TREES C.6500 YEARS AGO (Figure 7)

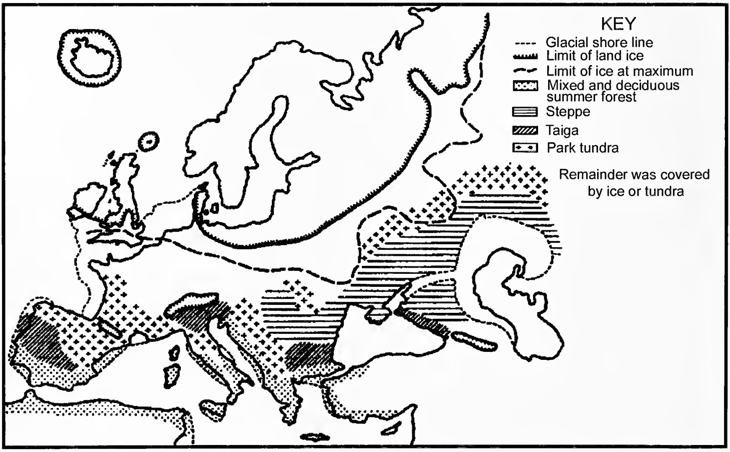
There is little evidence for Scots pine being a major component of central Scottish woodlands (Dickson et al., 2000). It was however the principal tree in the Highlands with tree birches and hazel dominating the Outer Hebrides and Northern Isles. By the time of maximum woodland expansion low lying, mainland Scotland north to the Great Glen was in the zone of oak dominance, with wych elm, alder and ash. Soil conditions determined woodland composition. Small amounts of Scots pine grew on drier areas of peat bog.

Figure 3. Ice sheets in the northern hemisphere



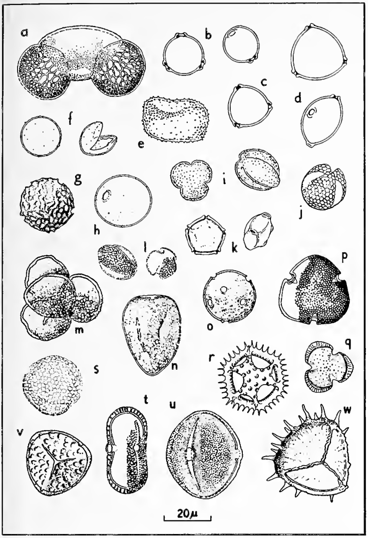
Source: Lamb & Sington, 1998

Figure 4. European vegetation at last ice glaciation



Source: Simms, 1990

Figure 5.



Drawings of pollen grains and spores frequently recognised in samples from British peats, lake muds and archaeological layers. a. Scots Pine, b. Tree Birch, c. Dwarf Birch, d. Hazel, e. Yew, f. Juniper, g. Wych Elm, h. Poaceae (Grasses), i. Oak, j. Ash, k. Alder, l. Willow, m. Heather, n. Cyperaceae (Sedges and related plants), o. Ribwort Plantain, p. Small-leaved Lime, q. Mugwort, r. Dandelion-type, s. Pondweed, Hogweed-type, u. Common Rock-rose, v. Bogmoss, w. Lesser Clubmoss. 1 micron = one thousandth of a mm. From Pigott and Pigott (1959)

Source: Dickson & Dickson, 2000

Table 1: British Native Tree Species

Bold = 15 species of natural woodlands.
Non-bold = species found in non-woodland habitats.(except *Arbutus*, wild now in Ireland, not in Britain)
*= not native in Scotland (Mitchell, 1974)

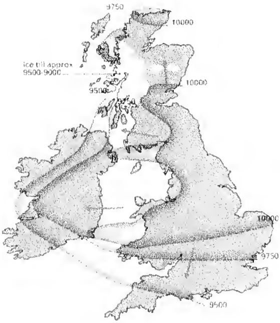
Alder (*Alnus glutinosa*)
Crab Apple (*Malus sylvestris*)
Ash (*Fraxinus excelsior*)
Aspen (*Populus tremula*)
***Beech (*Fagus sylvatica*)**
Silver Birch (*Betula pendula*)
Downy Birch (*Betula pubescens*)
Blackthorn (*Prunus spinosa*)
*Box (*Buxus sempervirens*)
Bird Cherry (*Prunus padus*)
Wild Cherry, Gean (*Prunus avium*)
Wych Elm (*Ulmus glabra*)
Hazel (*Corylus avellana*)
Hawthorn (*Crataegus monogyna*)
Holly (*Ilex aquifolium*)
***Hornbeam (*Carpinus betulus*)**
Juniper (*Juniperus communis*)
***Small-leaved Lime (*Tilia cordata*)**
Broad-leaved Lime (*Tilia platyphyllos*)
*Field Maple (*Acer campestre*)
Pedunculate Oak (*Quercus robur*)
Sessile Oak (*Quercus petraea*)
*Wild Pear (*Pyrus communis*)
Scots Pine (*Pinus sylvestris*)
Black Poplar (*Populus nigra*)
Rowan (*Sorbus aucuparia*)
***Wild Service Tree (*Sorbus torminalis*)**
*Strawberry Tree (*Arbutus unedo*)
*Whitebeam (*Sorbus aria*)
Almond Willow (*Salix triandra*) (probably not native to Scotland, Stace, 1997)
Bay Willow (*Salix pentandra*)
Crack Willow (*Salix fragilis*)
Goat Willow (*Salix caprea*)
White Willow (*Salix alba*)
Grey Sallow (*Salix cinerea*)
Yew (*Taxus baccata*)

Source: Miles, 1999

Figure 6a. Isochrone Contour Maps

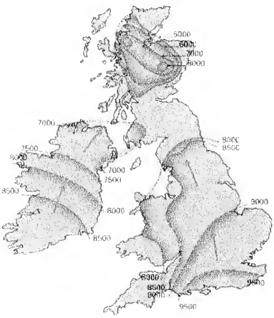
Spread of tree species

Data from Prof. Birks of Bergen using radiocarbon dated pollen samples



Birch *(Betula pubescens* and *B. pendula)*

Hazel *(Corylus avellana)*



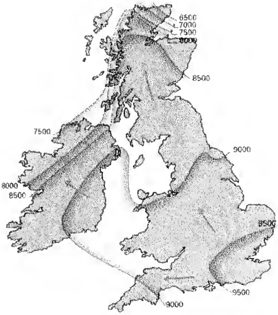
Pine *(Pinus sylvestris)*

Alder *(Alnus glutinosa)*

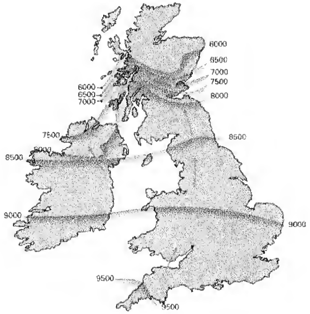
Source: Milner, 1992

Figure 6b. Isochrone Contour Maps

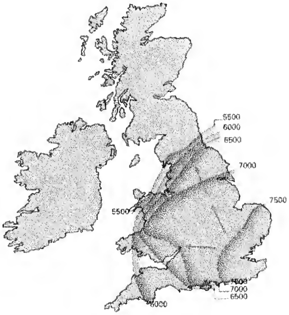
Arrows give direction of spread.
Lines represent limit of spread at the date before present.



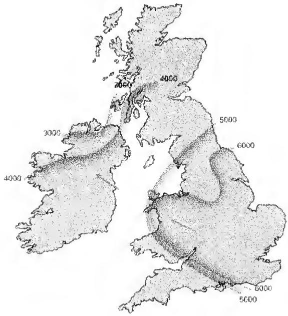
Elm *(Ulmus* species*)*



Oak *(Quercus* species*)*



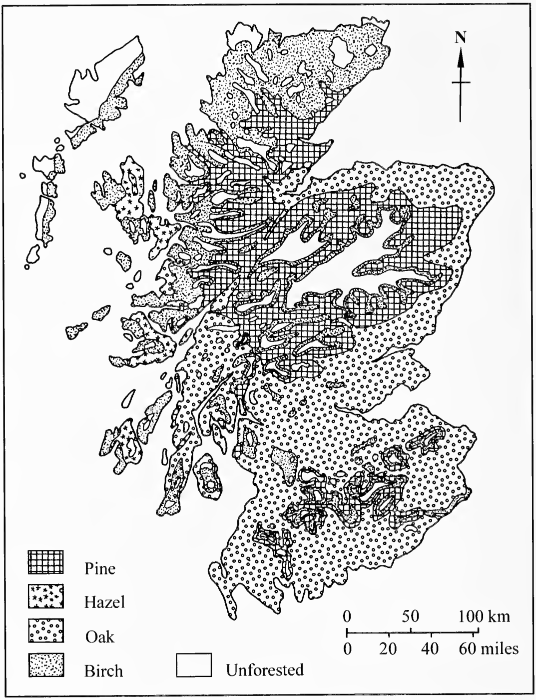
Lime *(Tilia cordata* and *T. platyphyllos)*



Ash *(Fagus sylvatica)*

Source: Milner, 1992

Figure 7. Woodland cover of Scotland several thousands of years ago, before woodland clearance had begun.



Source: Dickson & Dickson, 2000

Within a thousand years of the maximum a dramatic reduction in elm occurred, primarily a result of disease but possibly enhanced by human activity. Pollen analyses from Lenzie Moss, Lochend Loch bog and Drumpellier show that extensive woodland clearance took place before 2000 years ago by Iron Age pastoralists. During the last two thousand years woodlands have grown and declined as a result of variations in both climate and human activity.

NATURALISED TREES (Table 2)

The native tree flora conspicuously lacks a spruce, fir, larch, beech or maple (Scott, 2002); but examples of all of these have been introduced to Scotland and have shown themselves capable of natural regeneration.

Table 2: Naturalised Trees

Naturalised refers to an alien plant that has become self perpetuating (Stace, 1997)

a) Most common naturalised trees. Source: Milner, 1992

Several common trees that were introduced to these islands over the past few hundred years have since become naturalised. For instance, the Sycamore (*Acer pseudoplatanus*), which originated in central Europe, is now one of our most common trees, invading much of our scrub and woodland and growing vigorously as far north as the Shetlands and at altitudes of up to 460m. in mountain areas. The following is a list of the most common naturalised species, with their approximate dates of introduction:

Norway spruce *Picea abies* Native in last glacial period Reintroduced early 14th centurySweet chestnut *Castanea sativa* Introduced c. 100 AD
Sycamore*Acer pseudoplatanus*
Introduced c. 1250AD
Walnut *Juglans regia*
Introduced before 1000AD
White poplar *Populus alba* Early 14th century
Plane *Platanus orientali* 1350
Holm oak *Quercus ilex* 1580
Silver fir *Abies alba* 1603
Horse chestnut *Aesculus hippocastanum* 1616
European larch *Larix deciduas* 1620
False acacia *Robinia pseudoacacia* 1630

b) referred to as regenerating in 'The Changing Flora of Glasgow', 2000:

Laburnum *Laburnum anagyroides* 1560
Norway maple *Acer platanoides* 1638
Turkey oak *Quercus cerris* 1735
Grey alder *Alnus incana* 1780
Sitka spruce *Picea sitchensis* 1831
Lawson's cypress *Chamaecyparis lawsoniana* 1854
Balsam poplar *Populus trichocarpa* 1880
Ontario poplar *Populus candicans* ('Aurora') 1925
22 x willows
+ beech, hornbeam, field maple and lime (not native to Scotland but naturalised).

The dates of introduction are derived mainly from Wilkinson, 1981; also Campbell-Culver, 2001 and J. Dickson, pers. comm.

THE LAST 200 YEARS

The Gingko, a 'fossil' tree unaltered for 200 million years native to China, and Chile pine are examples of trees introduced in the 18th century. However the previous two centuries have seen an explosion in the number of tree species introduced to these islands as a result of the activities of the great plant hunters such as Menzies, Douglas, Fortune, Lobb, Forrest and Wilson.

Five of the more remarkable examples of conifer introductions are as follows. Three conifers from the Pacific North-west have grown to more than 200 feet in Britain: Sitka spruce, Douglas fir and grand fir.

Sitka Spruce.

Sitka spruce is regarded by foresters as the 'designer tree'. It has an extraordinary natural range of 1500 miles with uniform features. It is widely planted in poor, upland, acidic peat soils, where it can grow rapidly to produce a marketable stand of high quality timber from areas that are otherwise non-productive. It forms the most productive woods in the temperate world. Forest policy has introduced a random planting pattern of alternative species to replace the " serried ranks of conifers" so derided by conservationists.

Douglas fir.

The tallest 50 trees in the UK are Douglas firs and the tallest two are located in Glendaruel, Argyll and Moniack Glen, Beauly (Alderman, 2002).

The Grand Fir

The grand fir at Cairndow, Argyll was the first in the country to achieve 200 feet and for a while held the title of tallest tree in GB.

The Coastal Redwood.

The coastal redwood, *Sequoia sempervirens*, is the tallest tree in the world, found growing in the coastal fog belt of N. California. It survives up to 2000 years.

The Giant Sequoia

The giant Sequoia, *Sequoiadendron giganteum*, from the Sierra Nevada, has the biggest volume of any tree in the world. Within 80 years of its introduction in 1853 it was the biggest tree by volume in every county of GB. The largest are c.4000 years old. Both of these trees grow exceptionally well in our climate.

Many broadleaved trees have been introduced during this period but in height none of them remotely approaches that of champion conifers. Aesthetically however many of them surpass native species. Bright autumn tints distinguish introduced trees such as Japanese maples from the less bright natives. Furthermore the bark of species such as the Snake barked maple and Tibetan cherry is something to be marvelled at.

The 20th century has seen a reduction in the number of foreign trees being introduced but two may be mentioned:

The Dawn redwood, *Metasequoia glyptostroboides*, was known from Pliocene fossils when it was found in Hupeh province in 1941. Now there is one in most arboreta.
The Bristlecone pine, *Pinus aristata*, from the Rockies is closely related to *P. longaeva*, the oldest living tree at 5000 years.

THE CURRENT STATUS OF BRITISH NATIVE TREES

Most tree habitats in Britain have a long history of human interference and so it could be argued that there are no natural habitats left. Introduced specimens of a particular species bring alien pollen into the landscape and so pollute the native species. Many populations are only vaguely related to our original post-glacial trees. Small-leaved lime is the most researched species in this category. Isolated coppice stools are known that date back 2000 years. For hundreds of years the climate has not suited small-leaved lime particularly well but recent warm summers have encouraged the species to produce fertile seeds again (Gray & Grist, 2000). The native black poplar is very rare on account of the introduction of more productive hybrid timber trees (Miles, 1999). Willows are often adulterated by promiscuity, e.g. the grey willow (*Salix cinerea*) forms with other species three hybrids named in 'The Changing Flora of Glasgow' and five in the British Isles (Stace, 1997). Furthermore as many as 18 species of willow (including shrubs) may be found in Britain (Lusby, 2001). Imported beech and oak have caused considerable genetic pollution of existing trees. It has been argued that since common oak was better for shipbuilding purposes it was introduced to Scotland in preference to sessile oak with the result that much hybridisation with the local sessile species occurred.

MAN & NEW ECOSYSTEMS

Man has created entirely new ecosystems and some examples of these are as follows:

Heather Moorlands

Heather moorlands are largely an artifact (Gimingham, 1975). Along exposed coasts and at high altitude where trees compete poorly moors are natural. However the treeless tracts of heath that cover the Scottish highlands only appeared with the arrival of man and sheep grazing. Burning and grazing have prevented the heaths from returning to forest for thousands of years. With the decline in profitability of sheep grazing heath is being replanted with more profitable forests over much of its range. It is debatable whether this is a return to a natural state. Britain was heavily forested before the arrival of pastoralists. However burning and grazing for such a continuous length of time has arguably changed what is natural for these lands. On many heaths tree seed is so scarce that even when burning is halted and sheep removed forests do not immediately return. Many wild species have grown dependent upon these artificial ecosystems, including a number of endangered Arctic birds.

Chalk Fauna of the Downs

The unique chalk flora of the downs is an assemblage of light demanding plants that could never have flourished in the pre-settlement forests. This chalk and limestone grassland habitat possesses a wide variety of alkaline tolerant plants on the thin, dry and nutrient poor soils. The large blue butterfly is a species that requires wild thyme and ant grubs, *Myrmica sabuleti*, which rely on such close-cropped grasslands (Asher *et al.*, 2001). Since the decimation of rabbits in the 1950's by the introduction of myxomatosis the grass has grown taller, the wild thyme and ants scarcer, and the butterfly is in trouble. Yet the rabbit was itself an alien introduction of mediaeval times; it was imported from the continent and kept for food and fur. So what is natural is debatable. Perhaps a landscape with alien rabbits and native blue butterflies or one without either.

Linear Features

Studies have found that many artificial linear features in the landscape - hedges, roadside verges and ditches, for example – often support a greater diversity of life than is found in the open countryside. Roadside vegetation serves as a breeding habitat for 20 of 50 native mammals, 40 of 200 birds, all 6 reptiles, 5 of 6 amphibians and 25 of 60 butterflies. Such vegetation also serves as corridors linking larger areas of wildlife habitat and so increase the chances of a species survival.

Agriculture

Agriculture has been practised for thousands of years. All the recent gains in production have come through technological improvement rather than clearing more land.

Timber

Some 75% of the total world production of commercial timber comes from temperate forests, almost entirely from lands that have been managed for sustained timber production for more than half a century. These plantations could meet the entire world's timber needs on a mere 5% of the area of all the world's existing forests.

ANIMAL BIODIVERSITY (KITCHENER, 1998)

There were two main causes of extinction of mammals since the end of the last Ice Age:

1. Climate change created new habitats where cold adapted species could no longer survive, e.g. reindeer
2. Human activity by a) hunting, e.g. polecat b) habitat destruction for agriculture e.g. lynx and c) hybridisation between native and introduced species.

Table 3 gives examples of other mammals that have become extinct since the last Ice Age.

Several large species were dependent on forest habitats, e.g. beaver, wolf, brown bear, lynx, wild pig and moose, but by the 18th century Scotland

Table 3: Extinction of land mammals in Scotland since the end of the last Ice Age.

Species	Date/Time when lost	Causes of extinction
Giant deer (*Megaloceros giganteus*)	?Mesolithic	C
Wild horse (*Equus ferus*)	?Mesolithic	C, ?X, ?K
Reindeer (*Rangifer tarandus*)	?Mesolithic	C
Auroch (*Bos primigenius*)	Bronze age (c. 3500 years ago)	?H, ?K
Moose (*Alces alces*)	Bronze age (c. 3500 years ago)	?H, ?P/K
Brown bear (*Ursus arctos*)	Roman times (or ?10th C. AD)	H, P/K
Beaver (*Castor fiber*)	c. 1550 AD	?K, ?H
Wild boar (*Sus scrofa*)	c. 1600 AD	?K, ?H, ?X
Wolf (*Canis lupus*)	1743 AD	P, ?H
Lynx (*Felis lynx*)	1770 AD	?H, ?P/K
Red Squirrel (*Sciurus vulgaris*)	c. 1800 AD	H, ?D
Polecat (*Mustela putorius*)	c. 1912 AD	P, ?K

Key: C – climate change; D – disease; H – habitat loss; K- hunting; P – persecution; X – hybridisation with domestic species.
Sources: Kitchener, 1998, 2001 and Humphrey & Quine, 2001

was amongst the most deforested countries in Europe. The large mammals had become extinct except for red deer which adapted to open moorland. Even the red squirrel may have become extinct. Most of today's population derives from introductions in the 18th and 19th centuries from England and Scandinavia. The red squirrel today may be declining because of its inability to digest acorns (Thomas, 2000). The acorns contain a digestive inhibitor that greys can ameliorate but reds cannot. Hence reds are more successful in conifer plantations where they feed on more nutritious pine seeds and where there are no oaks to give greys a competitive edge.

Bird extinctions have three main causes (Table 4):

Habitat loss. Wetland drainage has resulted in the loss of larger birds such as crane, bittern and white stork. The capercaillie became extinct as the Caledonian pine forest declined. It breeds in coniferous woodland from Norway to Siberia, with glacial relics in the Alps & Pyrenees. Birds of Swedish stock were re-introduced to Perthshire in 1837. From there they have colonised the E. Highlands and Loch Lomondside, where the islands contain amongst the highest densities in Scotland (Mitchell, 2001).

Hunting. The great auk, for example, was hunted to extinction. The last known British specimen was killed on Stac an Armin, St. Kilda, in 1840.

Persecution. Birds of prey suffered severe persecution from gamekeepers, sportsmen and farmers, e.g. osprey (returned to Scotland in 1954 to Loch Garten, eyrie built in Scots pine), goshawk, white-tailed sea eagle and red kite.

The overall temperature drop of each glaciation drove the bird population E, SE & S with the retreating vegetation. The birds returned N & W in a process that continues today. In the last 100 years > 20 species have thus extended their range. Yet > 50 species nest regularly in Britain but not in Ireland, a phenomenon not easily explained.

Mammal introductions: There are three main reasons for which mammals have been introduced (Table 5):

1. Aesthetic e.g. fallow deer
2. Accidental e.g. ship stowaways, such as rats; escapees such as rabbits
3. Sport e.g. sika deer, brown hares

Invertebrates and trees.

The number of invertebrates found on native trees is much greater than that found on introductions, although non-native conifer species appear to provide suitable habitat for a wide range of native fauna (and flora) (Humphrey & Quine, 2001). Some 500 species are associated with oak and 450 with the genus *Salix*. Most of these are insects, particularly moths and beetles. Of course rarity can be as important as sheer numbers, e.g. endangered species found on aspen are the aspen hover fly and the rare dark bordered beauty moth. The SWT hopes to create aspen corridors to keep these rare insects in existence.

Table 6 summarises gains and losses of mammals and birds since the last ice age.

The number of birds and mammals lost or gained is in itself less important than the effect of losses or introductions on the indigenous fauna. The absence of top mammalian carnivores causes much ecosystem imbalance such as an excess of deer leading to a lack of young trees. It has to be said that animal introductions have proved to be far more devastating than plant introductions.

Mink and water voles

The American mink was first brought to Britain in the late 1920's to be farmed for its fur. However it escaped into the wild in 1938, colonised successfully and is now implicated in the severe decline of the water vole (Kitchener, 1998).

Table 4. Extinction of birds in Scotland since the end of the last Ice Age.

Species	***Date of Extinction in Scotland (Date of Global Extinction)***	***Cause of Extinction.***
Bittern (*Botaurus stellaris*)	1830 AD	P
Osprey (*Pandion haliaetus*)	1916 AD	P
Sea Eagle (*Haliaeetus albicilla*)	1918 AD	P
Red Kite (*Milvus milvus*)	1884 AD ?1917 AD	P
Goshawk (*Accipiter gentilis*)	1883 AD	P
Capercaillie (*Tetrao urogallus*)	1785 AD	H, K
Spotted Crake (*Porzana porzana*)	1912 AD	H
White Stork (*Ciconia ciconia*)	1416 AD*	?H
Great Auk (*Pinguinus impennis*)	1840 AD (1844 AD)	K
Crane (*Grus grus*)	?	K, H
Great Bustard (*Otis tarda*)	16th C AD	?H, ?K
Great Spotted Woodpecker (*Dendrocopos major*)	1840-1850 AD	H

H = Habitat loss. K = Hunting. P = Persecution. Source: Kitchener, 1998.

Table 5. Introductions of land mammals to Scotland since the end of the last Ice Age.

Species	***Date of arrival AD***	***Purpose***	***Success (last record)***
Red-necked Wallaby (*Macropus rufogriseus*)	1975 AD	A	Y
American Mink (*Mustela vison*)	1938 AD	E	Y
Fallow Deer (*Dama dama*)	900 AD	K, A	Y
Sika Deer (Cervus nippon)	1870 AD	K, A	Y
Wapiti (*Cervus canadensis*)	1819 AD	K	N
White-tailed Deer (*Odocoelius virginianus*)	1832 AD	? K, ? A	N (1872)
Grey Squirrel (*Sciurus carolinensis*)	1892 AD	A	Y
Canadian Beaver (*Castor canadensis*)	1875 AD	A	N (1903)
Muskrat (*Ondatra zibethicus*)	1927 AD	E	N (1937)
Orkney Vole (*Microtus arvalis*)	3700 BC – 3400 BC	E	Y
House Mouse (*Mus domesticus*)	Iron Age	E	Y
Black Rat (*Rattus rattus*)	Iron Age or 1st C AD	E	N*
Brown Rat (*Rattus norvegicus*)	? 1730's; 1744-1754	E	Y
Rabbit (*Oryctolagus cuniculus*)	13th C	E	Y
Brown Hare (*Lepus europaeus*)	? 1st C	K	Y

A = Aesthetic. K = Hunting. E = Accidental .
N = No. Y = Yes. Source: Kitchener, 1998.
** excluding population on Shiants.*

Table 6: Birds & Land Mammals: Numbers of Species Gained and Lost Since End of the Last Ice Age in Scotland

Native Mammals extinct = 12
Re-introductions = 1
Net loss = 11

Native Birds extinct = 12
Re-colonisation & re-introduction = 7
Net loss = 5

Alien colonisations & introductions:
Mammals = 15 (4 unsuccessful) = 11
Birds = 44 (4 unsuccessful) = 40
Totals = 51

Net gains/(losses):	Mammals	Birds
Net gains	11	40
Net losses	11	5
Totals:	0	35

Sources: Summary of Tables 3, 4, 5 and, for bird introductions, Kitchener, 1998

The powan

The powan is a relict cold water fish confined to a few mountain lochs. In Loch Lomond the introduced ruffe is a significant predator of its eggs. So reserve stocks of this legally protected fish have been introduced to Loch Sloy and the Carron Reservoir (Mitchell, 2001).

The introduced NZ flatworm

The introduced NZ flatworm has a negative impact on native worms and is spreading rapidly.

Crayfish

The aggressive and invasive signal crayfish (*Pacifastacus leniusculus*) has almost wiped out the native white-clawed species (*Austropotamobius pallipes*) (Maitland *et al*., 2001).

Anyone wishing to discover more about the controversial topic of 'Alien species: friends or foes?', especially in a Scottish context, need look no further than the publication of the proceedings of the symposium about this topic held in 2001 to celebrate the Society's 150th anniversary.

Although this has been a wide ranging address, the world of micro-organisms has not been mentioned, but I hope to have demonstrated that whereas plant introductions have overall provided a welcome increase in this country's biodiversity animal introductions are proving to be far more controversial.

ACKNOWLEDGEMENTS

For providing me with slides to illustrate this address I thank Ewen Donaldson of Glasgow Botanic Gardens, Mogens Hansen of the Society, Frank Morris of St. Aloysius' College, Glasgow and Richard Sutcliffe of Kelvingrove Museum.

For helpfully commenting on a draft of the manuscript I thank Prof. Jim Dickson and Dr. Petra Mudie, as well as Keith Watson and Bernard Zonfrillo of the Society.

REFERENCES

Alderman, D. (2002). Registrar's Report. *The Tree Register Newsletter No.11*. The Tree Register of the British Isles, Bedford.

Asher, A. *et al*. (2001). *The Millennium Atlas of Butterflies in Britain and Ireland*. Oxford University Press, Oxford.

Budiansky, S. (1995). *Nature's Keepers*. Phoenix, London.

Campbell-Culver M. (2001). *The Origin of Plants*. Hodder Headline, London.

Dansgaard, W., White, J.W.C. and Johnsen, S.J. (1989). The abrupt termination of the Younger Dryas. *Nature* 339, 532-534.

Dickson, C. & Dickson, J.H. (2000). *Plants & People in Ancient Scotland*. Tempus, Stroud.

Dickson, J.H., Macpherson P. and Watson K. (2000). *The Changing Flora of Glasgow*. Edinburgh University Press, Edinburgh.

Ennos, R.A., Sinclair, W.T. and Perks, M.T. (1997). Genetic Insights into the Evolution of Scots pine, *Pinus sylvestris* L., in Scotland. *Botanical Journal of Scotland* 49 (2), 257-265.

Farrow, G.E. (2001). James Croll: 19th Century Pioneer of Climate Change. *The Glasgow Naturalist* 23 (6), 9-18.

Fischer, H., Wahlen, M., Smith, J., Mastroianni, D. and Deck. (1999). Ice core records of atmospheric CO_2 around the last three glacial terminations. *Science* 283, 1712-1714.

Fitter, R. (1967). *The Penguin Dictionary of British Natural History*. Penguin Books, Middlesex.

Gimingham, C.H. (1975). *An Introduction to Heathland Ecology*. Oliver & Boyd, Edinburgh.

Gootes, P.M., Stuiver, M., White, J.W.C., Johnsen, S. and Jonzel, J. (1993). Comparison of oxygen isotope records from the GISP2 and GRIP Greenland ice cores. *Nature* 336, 552-554.

Gray, R.K.S. and Grist, N.R. (2000). Natural regeneration of limes (*Tilia* spp.) in Scotland: locally widespread and more numerous in 1999. *The Glasgow Naturalist* 23 (5), 13-16.

Gribben, J. and M. (2001). *Ice Age*. Penguin Books, London.

Hadfield, M. (1996). *Pioneers in Gardening*. Bloomsbury.

Haeckel, E. (1866[1988]). *Generelle Morphologie des Organismus, Bd.2: Allgemeine Entwicklungsgeschichte*. Reprint. Berlin: de Gruyter.

Humphrey, J. and Quine, C. (2001). Sitka spruce plantations in Scotland: friend or foe to biodiversity? *The Glasgow Naturalist* 23 Supplement 66-76.

Huntley, B., Daniell, J.R.G. and Allen, J.R.M. (1997). Scottish vegetation history: the Highlands. *Botanical Journal of Scotland* 49 (2), 163-175.

Idso, S.B. (1989). CO_2, soil moisture and future crop production. *Soil Science* 147, 305-307.

Johnsen, S.J., Clausen, H., Dansgaard, W., Fuhrer, K., Gunderstrup, N.S., Hammer, C.U., Iverssen, P., Jouzel, J., Stauffer, B. and Steffensen, J.P. (1992). Irregular glacial interstadials recorded in a new Greenland ice core. *Nature* 359, 311-313.

Johnson, H. (1993). *The International Book of Trees*. Mitchell Beazley, London.

Kitchener, A.C. (1998). Extinctions, Introductions and Colonisations of Scottish Mammals and Birds since the Last Ice Age. Pp. 63-92 in Lambert, R.A. (editor) *Species History in Scotland*. Scottish Cultural Press, Edinburgh.

Lamb, S. and Sington, D. (1999). *Earth Story*. BBC Books, London.

Lambert, R.A. ed. (1998). *Species History in Scotland.* Scottish Cultural Press, Edinburgh.

Lusby, P. and Wright, J. (2001). *Scottish Wild Plants.* Mercat Press, Edinburgh.

Maitland, P.S., Sinclair, C. and Doughty, C.R. (2001). The status of freshwater crayfish in Scotland in the year 2000. *The Glasgow Naturalist* 23 (6), 26-32.

Marren, P. (1990). *Woodland Heritage.* David & Charles, Devon.

Miles, A. (1999). *Silva.* Ebury Press, London.

Milner, J. E. (1992). *The Tree Book.* Collins & Brown, London.

Mitchell, A. & Coombes, A. (1998). *The Garden Tree.* Weidenfeld & Nicolson, London.

Mitchell, A. (1974). *A Field Guide to the Trees of Britain and Northern Europe.* Collins, Glasgow.

Mitchell, A. (1996). *Trees of Britain.* HarperCollins, London.

Mitchell, J. (2001). *Loch Lomondside.* HarperCollins, London.

Morton, A. (1998). *Tree Heritage of Britain and Ireland.* Swan Hill Press, Shrewsbury.

Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N.L., Barnola, J.-M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyskov., V. M., Legrand, M., Lipenkov, V.Y., Lorius, C., Pepin, L., Ritz, C., Saltzman, E. and Stievenard, M. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399, 429-436.

Ramsay, S. and Dickson, J.H. (1997). Vegetational history of central Scotland. *Botanical Journal of Scotland* 49 (2), 141-150

Rigozo, N.R., Echer, E., Vieira, L.E.A. and Nordemann, D.J.R. 2001. Reconstruction of Wolf sunspot numbers on the basis of spectral characteristics and estimates of associated radio flux and solar wind parameters for the last millennium. *Solar Physics* 203, 179-191.

Salisbury, F.B. and Ross, C.W. (1978). *Plant Physiology.* Woodsworth Publishing Co., Belmont CA.

Scott, A. (2002). *A Pleasure in Scottish Trees.* Mainstream, Edinburgh.

Simms, E. (1990). *Woodland Birds.* Collins, London.

Smith, A. (1997). *All for a Handful of Seed.* Smith A.K., Perth.

Smout, T.C. ed. (1997). *Scottish Woodland History.* Scottish Cultural Press, Edinburgh.

Stace, C. (1997). *New Flora of the British Isles.* Cambridge University Press, Cambridge.

Thomas, P. (2000). *Trees: Their Natural History.*Cambridge University Press, Cambridge.

Wilkinson, G. (1981). *A History of Britain's Trees.* Hutchinson, London.

Glasgow Naturalist 2002. Volume 24 Part 1. Pages 15-22.

CLIMATE CHANGE. ITS HISTORY AND FUTURE IN RELATION TO SCOTLAND'S LANDSCAPE, PEOPLE, AND ECONOMY

EDITORIAL.

Azra Meadows and Peter Meadows
Division of Environmental and Evolutionary, Biology, Graham Kerr Building, Institute of Biomedical and Life Sciences, University of Glasgow G12 8QQ

INTRODUCTION

'Flavit et dissipati sunt'

(It blew and they were scattered)

Unusually changeable weather conditions occurred around Britain from 1500 to 1800, ending with the mini ice age in the late 18th century. Major North Sea storms developed in 1530, 1570, 1634, and 1697, and 1694 the Culbin sands, just west of Nairn on the Moray Firth coast, shifted significantly during very high winds. A less dramatic storm occurred in September 1588. However this one changed history as it destroyed many of the ships of the Spanish Armada, and as a result Queen Elizabeth I of England issued a commemorative medal inscribed 'Flavit et dissipati sunt' - referring to the Spanish Armada. So climate change of one sort or another is a normal feature of UK weather, and we can expect more of it during the coming decades. There are a number of excellent general and more technical accounts (Harding, 1982; Libby, 1983; Shackleton et al, 1988; Leggett, 1990; Ribot et al., 1996; Curran, S. 1998; Department of the Environment, n.d.; Drake, 2000 - reviewed by the authors in this volume; Cookson, 2002). We address this very topical subject in our article, focussing on the importance of climate change for Scotland. James Croll was also very much aware of this in the last century, as Farrow points out in a recent and most elegant paper in the Glasgow Naturalist (Farrow, 2001).

We begin by emphasising the importance of the interaction between mountains, rivers and the coastal zone in relation to climate change. This is followed by a consideration of historical evidence for climate change in Scotland and England. We then consider current views on climate change and the importance of greenhouse gases in determining weather patterns and global warming. Predicted climate and weather change in Scotland has been the subject of an exhaustive recent study by Kerr, Shackley, Milne and Allen (1999) entitled 'Climate Change : Scottish Implications Scoping Study'. In the last part of our article we discuss and comment on some of the major points raised by this study, which was commissioned by the Scottish Executive Central Research Unit. As is often the case in government reports, there are some very specific points raised, but a great deal of generality.

MOUNTAINS, RIVERS AND THE COASTAL ZONE AS AN INTERACTING ENVIRONMENT

Mountains rivers and the coastal zone are extremely important interrelated ecosystems on a global scale that act together in terms of responding to and often influencing global climate change. Until very recently few scientists realised their integrated nature, and the central part they play in climate change and in controlling the living conditions of human populations - including the resources of land and water (Dobby 1962; Groombridge 1992). This is especially relevant for Scotland, in terms of predictions of climate change and global warming (Manley, 1975; Ford, 1982; IUCN 1990; Houghton et al. 1996; Watson, Zinyowera & Moss 1996; Batterbury, Forsyth & Thompson 1997).

Scotland is made up of mountains, hills and rivers, and is surrounded by a coastline that is often indented by extensive marine loch systems. It also contains magnificent freshwater lochs, vast tracts of uninhabited highlands in its centre, and habitats that contain many rare and endangered species of plants and animals. Its weather is relatively dry on the east coast, wet on the west coast, and in the central highlands alternately very cold in winter and warm in summer. Its large cities, Glasgow, Edinburgh, and Aberdeen, perhaps belie the essentially rural nature of the country. The existence of much of the human population is in scattered villages and small towns around the coast connected by coastal road systems, together with a few highland villages joined by small roads that cross inhospitable but very beautiful country. Scotland has been shaped in the past by large glaciers during the most recent ice age that only ended approximately 12,000 years ago. Its whole landscape of mountains, glens, rivers, lochs and coast have been shaped by these events. How will climate change alter this? Table 1 summarises some of the more important aspects of how climate change will affect natural and human impacts on these systems. Many of these aspects are of direct relevance to Scotland, as an inspection of the asterisked items show. They include decreased snow cover, deforestation, erosion, flooding, sea level rise, storms, and sea defences.

In Scotland as elsewhere, the erosion of hillsides and mountains is a natural process. Rain and snow feed mountain streams and cause periodic flash floods. The rain, snow, streams and flash floods carry water down hillsides and at the same time cause erosion. This erosion consists of sedimentary material - small rocks, stones and soil particles - carried along by the water. The whole process feeds water and sediment into the main branches of a river that lie at lower levels.

Periodic river floods in the lower reaches of rivers

distribute water and fine sediment onto the flatter country there, thus producing good agricultural land. It is not often appreciated that the soil cultivated by present day man has been transported there from mountainous areas in past geological periods. This soil has been transported by the continuous action of melting glaciers in the past the present day action of rivers, and by the floods. Eventually rivers discharge both their water and fine suspended sediment into the coastal marine environment. The huge mud and sand banks in as a habitat for the small invertebrates that migrating birds feed on.

The mountains, rivers and the coastal zone of Scotland have therefore to be considered as a series of contiguous interacting ecosystems, in which water and sediment are transported from high mountain environments, onto river basins to form rich agricultural land, and then to the coastal zone and into the oceans. The implications of this, and of future changes in the climate over Scotland in terms of human habitation, resource potential and biodiversity cannot be overemphasised. On a global stage this has been recognised by the 1992 Rio Earth Summit on Biodiversity, the 1997 Earth Summit II in New York, the Kyoto Climate Summit in December 1997, together with international scientific conferences such as the Indus River meeting in 1994 (Meadows & Meadows 1999b). These initiatives show that at last political and scientific communities are becoming aware of the future dangers and threats.

Table 1. Global climate change and Natural and human impacts on mountains, rivers and coastal zones. *Major impact of climate change likely. (Modified from Meadows & Meadows 1999a).

TYPE OF ENVIRONMENT	IMPACT	PROCESS	OUTPUT	ENVIRONMENTAL MANAGEMENT
Hills and Mountains	Natural impact.	Melting of glaciers*, decreasing snow cover*, weathering of rocks.	Water discharge, soil erosion.	Prevention of build-up of greenhouse gases*.
	Human impact.	Deforestation*, erosion*.	Soil erosion, silting.	Reforestation*, managed land use.
Rivers and Flood plains	Natural impact.	Flooding*.	Soil, particulates, salts, water discharge.	Flood control defences*, dams, barrages, dykes.
	Human impact.	Water logging, desertification* salinisation.	Abandoned agricultural land.	Construction of outfall drains.
		Industrial, domestic pollution.	Pollutant discharge, water quality.	Pollution control.
Coastal Zones Estuaries and Firths	Natural impact.	Sea level rise.* Storms*.	Flooding of low lying coastlines*.	Coastal defences*.
		Hurricanes, cyclones.	Loss of human life, habitat.	Weather predictive models, satellites.
	Human impact.	Industrial and domestic pollution.	Decline in fisheries*. Eutrophication*.	Pollution monitoring.
		Over-exploitation of natural resources.	Depletion of natural resources.	Managed resource exploitation*.
		Habitat degradation.	Loss of nursery grounds for fish.	Conservation, protection.

HISTORICAL CLIMATE CHANGE IN SCOTLAND AND ENGLAND

Climate change is not new, as we have seen. The following contemporary quotations from Baker (n.d. In fact c. 1883 - editors) describe unusual and often catastrophic weather changes over Scotland and England. Many of them still have an immediacy.

764 AD: 'There fell such a marvellous great snow. and therewith so extreme a frost, as the like had not been heard of, continuing from the beginning of the winter almost till the midst of spring, with the rigour whereof trees and fruits withered away, and not only feathered fowls, but also beasts on the land and fishes in the sea died in great numbers Holenshed; Roger de Hoveden'.

793 AD: 'Dreadful prodigies alarmed the wretched nation of the English; for terrific lightnings and dragons in the air and strokes of fire were seen hovering on high, and shooting to and fro, which were ominous sighs of the great famine and the frightful and ineffable slaughter of multitudes of men which ensued (Roger de Hoveden)

800 AD: 'On the ninth day before the calends of January, the day before the Nativity of our Lord, a mighty wind, blowing either from the south or south-west, by its indescribable force destroyed many cities, houses, and towns in various places; innumerable trees were also torn up from the roots. In the same year an inundation took place, the sea flowing beyond its ordinary limits (Roger de Hoveden; M. of W.).'

1092 AD: 'By the high spring tides many towns, castles, and woods were drowned, as well in Scotland as in England. After the ceasing of the tempest, the lands that sometime were Earl Goodwin's, by violent force and drift of the sea were made a sandbed, and ever since have been called Goodwin's Sands. Such dreadful thunder happened also at the same time, that men and beasts were slain in the fields, and houses overturned even from their foundations. In Lothian, Fife, and Angus, trees and corn were burnt up by fire kindled no man knew how (Holenshed).'

1210 AD: 'Inundation at Perth about the time of the Feast of St Michael, which carried off much of the harvest crops from the fields. The waters of Tay and Almond so swelled that the large bridge of St John was overthrown (Fordun and Major).'

1333. AD. 'November 23. At night through a marvellous inundation and rising of the sea all along by the coasts of this realm but especially about the Thames, the sea banks or walls were broken down with the violence of the water, and infinite numbers of beasts and cattle drowned fruitful grounds and pastures were made salt marshes, so as there was no hope that in long time they should recover again their former fruitfulness (Holinshed).'

1771 AD: 'Dr Johnson says that the season was so severe in the Island of Skye that it is remembered by the name of the Black Spring. The snow, which seldom lies at all, covered the ground for eight weeks, many cattle died, and those that survived were so emaciated that they require no male at the usual season. The case was the same in the south; never were so many barren cows known as in the spring following that dreadful period. At the end of March the face of the earth was naked to a surprising degree. Wheat hardly to be seen, and no signs of any grass; turnips all gone, and sheep in a starving way. All provisions rising in price. Farmers cannot sow for want of rain (Gilbert White). May 6. By letters from Gloucester we learn that the late rains have produced such an alteration that everything promises a plentiful crop, though a late one.'

It is even possible to construct historical weather patterns from contemporary records. Kington's classic book on 'The Weather of the 1780's over Europe' (1988) shows what can be done by attention to detail and an inspection of the records of learned and scientific societies. These also show that climate change was happening the whole time, with unexpected storms, very hot summers or cold winters, and flooding. These records of meteorology began early in the European scientific and cultural renaissance of the 17th and 18th centures. In 1653, Ferdinand II, the Grand Duke of Tuscany and a member of the Medici family, arranged for a network of permanent meteorological stations to be set up in Italy.There were about 12 stations mainly in northern Italy, and data was entered on standard forms concerning pressure, humidity, temperature, wind direction and sky state. The data was collected largely using standard instruments, and then sent to Florence to the Accademia del Cimento (the Academy of Experiments). Unfortunately the system broke down when the Academy was disbanded in 1667. However Kinton (1988) reminds us that Robert Hooke, the first Curator of the Royal Society, proposed in 1667 'A Method for Making a History of the Weather'. He also designed instruments that included a barometer for use on land and at sea, an anemometer for measuring wind source base on a pressure plate, and a thermometer graduated with zero based on the freezing point of water. By 1723, the Royal Society of London was recording weather data in Weather Journals, with details of temperature, rain, wind, and sky state. In France things were also happening. The Société Royale de Médicine was established under Louis XVI, and by the mid 1780s there was a network of over 70 weather stations across France which was extended to receive information from America and Asia.

These and similar reports taken together show that climate change is happening the whole time. Perhaps the relative stability over the past half century may be an exception. But even here, many readers will remember the very cold winter of 1947 and 1963 - when the sea froze along parts of the

Scottish coastline. Temperatures of about -25°C occurred in the Kirklee area of Glasgow during one winter in the 1980's, -18°C over the Christmas and New Year period during one winter in the 1990's, and there was an extremely hot and dry summer in 1987.

CURRENT VIEWS ON CLIMATE CHANGE. THE IMPORTANCE OF GREENHOUSE GASES

Current views of potential climate change are focusing on temperature change, alterations in the amount and distribution of rainfall, change in sea level, and frequency and location of storms. However there is no universally accepted consensus in spite of the clear evidence that world temperatures have increased significantly since the beginning of the industrial revolution in the early 19th century, and that sea levels are rising on some coastlines.

Much of the recent change in temperatures, often referred to as global warming, is related to the increase in release of greenhouse gases. A quick explanation of the effect will help. The sun's energy warms the earth. This energy is absorbed by the earth and some of it is irradiated back into space as long wavelength infra red radiation. Greenhouse gases in the upper atmosphere stop some of this long wavelength infra red radiation leaving the earth's atmosphere and reaching space. As a result this radiation is trapped and the earth gets fractionally hotter - global warming..

The difficulty is the lack of precision in predictions. It is not possible to obtain an accurate prediction of the amount and distribution of global warming that is likely to occur. It is also very difficult to identify how much of the global warming that has taken place during the last 150 years is caused by man's activities as compared to natural long term perturbations in weather patterns. Atmospheric carbon dioxide, a major greenhouse gas, has certainly been rising since the beginning of the industrial
revolution in the early nineteenth century. Currently, the burning of fossil fuels contributes 80% of this and is rising at about 0.5% per year. World temperatures have broadly increased over the same period. Other greenhouse gases such as methane, nitrous oxide, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are being added to the atmosphere by man's activities (Table AAA). All of these gases will certainly add to global warming by acting as a blanket in the upper atmosphere. It is particularly worrying that CFCs and HCFCs have effects that are two or more orders of magnitude greater than methane or carbon dioxide (Table 2, column 2). For example HCFC 22 has 1600 times the effect of carbon dioxide, CFC 11 has 3400 times the effect of carbon dioxide, and CFC 12 has an amazing 7100 times the effect of carbon dioxide.

Table 2. Greenhouse Gases. Their approximate relative greenhouse effect (Global Warming Potential GWP). concentrations in the atmosphere (ppmv: part per million by volume), current rate of change (% per year), and atmospheric lifetime.
Global warming potential is the predicted reduction in the amount of heat radiated from the earth produced by a particular gas, in relation to the reduction produced by carbon dioxide over the same time period. It is only a very approximate measure of the relative effect of a greenhouse gas, as errors of up to 35% are recognised (Houghton *et al.*, 1996, p. 21).
* carbon dioxide does not have a single lifetime because the uptake rates differ for different processes. CFC = chlorofluorocarbons. HCFC = hydrochlorofluorocarbons.

Greenhouse Gases	Approximate relative Greenhouse effect G.W.P.	Current average atmospheric concentration (ppmv) (1992)	Current rate of change (%pa)	Atmospheric lifetime in years
Carbon dioxide	1	355	1.8	50 - 200*
Methane	11	1.72	0.8	12
Nitrous Oxide	270	0.31	0.25	120
CFC 11	3400	0.00026	4	50
CFC 12	7100	0.00045	4	-
HCFC 22	1600	0.0001	-	12

(Source: The Department of the Environment ND; Houghton *et al.*, 1996)

Predictions suggest an increase in global temperatures of 0.5°C to 2.5°C by 2030, which is likely to lead to a rise in sea level of between 10 cm and 20 cm. At first sight this does not seem very much, but in very low lying areas such as on the east coast of England and in some low lying areas of Scotland, the effects are likely to be catastrophic. These latter include all the major estuaries in Scotland, the area around Elgin, and some parts of Glasgow through which the Cathcart flows. Floods in these coastal regions caused by high river flows and by abnormally high sea levels associated with low atmospheric pressures - storm surges, can already cause large scale economic problems.

There may also be a change in weather patterns and increased frequency of severe storms. Even if worst case scenarios do not occur, it is undoubtedly true that within the last decade there have been significant changes in coastal weather. The southern parts of England have become much drier during summer. These changes are obvious even to the ordinary person, and are already having an impact on the economy of the areas affected. Conventional crops are suffering, and new cultivars are being assessed that can withstand drier, hotter conditions.

These changes are obvious even to the ordinary person, and are already having an impact on the economy of the areas affected. Conventional crops are suffering, and new cultivars are being assessed that can withstand drier, hotter conditions. Coastal areas short of drinking water are being forced to introduce water rationing, and desalination plants - once only seen in the more arid parts of the tropics.

PREDICTED CLIMATE AND WEATHER CHANGE IN SCOTLAND THE RECENT CCSIS STUDY

A recent 75 page study on climate change in Scotland, 'Climate Change : Scottish Implications Scoping Study' (the CCSIS study) published by the Scottish Executive Central Research Unit makes fascinating reading (Kerr, Shackley, Milne, and Allen, 1999). In some ways it is very specific, but in others it is somewhat vague.

There are likely to be a number of quite specific changes in climate and weather in Scotland during the 21st century. The weather will become warmer by about 1.2 to 2.6^{o} centigrade, with more warming occurring in winter than in summer. Rainfall intensity will increase, most noticeably in winter which will lead to higher risks of flooding. Severe gales will increase in number, and short-wave radiation will become reduced because of increased cloud cover.

The report identifies two possible megascale phenomena which although unlikely to occur would have profound implications for the climate, and hence for all biodiversity - ourselves included, during the present century. The first is a major alteration of the Gulf Stream and North Atlantic Drift oceanic circulation in the North Atlantic, which brings warm water to the western coasts if Ireland, Scotland and England. This would affect the climate of the whole of Europe and would probably lead to a mini-ice age in the region. The second is the collapse of the West Antarctic ice sheet which in turn would lead to an increase in the rate and degree of the rise in sea level.

climate change, but surprisingly little on means of adapting to climate change. Means of adapting to climate change can be natural or planned. Natural adaptations consist of biological change such as potential changes in bird migration patterns, human sociological changes, and potential changes in human outdoor activities. The authors define planned adaptations as those planned by man which may include such items as revisions of building codes and improved air conditioning systems. They also include consideration of the aims of a biodiversity policy for Scotland, stating that 'a static view of natural conservation is not viable'. The second aspect concerns policies that are intended to reduce human-induced climate change, and the impact of these policies on Scottish society. Specifically, the UK government is required to meet international obligations on reducing greenhouse gas emissions. It must reduce its emissions of the six most important greenhouse gases from a 1990 level of 216 million tonnes carbon equivalent, to 189 million tonnes carbon equivalent averaged over the period 2008 to 2012. The UK government has made an additional domestic target of reducing carbon dioxide emissions to 20% below international baselines over the same period.

Neither the first aspect nor the second aspect is in any way specific to Scotland, in our view, although the points are worthwhile making on a broader canvas. The CCSIS study goes on to report on two recent workshops organised by the Scottish Office in 1998.

Workshops

The first workshop focused on 'Climate Change Impacts in Scotland'. The conclusions of the workshop identified a need for higher resolution climate data for Scotland. There were also specific concerns about the impact of climate change on the following resources and infrastructure. 1. Salmon, marine and freshwater fisheries. 2. Oil and gas infrastructure. 3. Hydroelectric plant. 4. Roads, coastal defences and other public infrastructure. 5. Water resources. Highland and subarctic ecosystems. 6. Agriculture and forestry. 7. Skiing industry. 8. Health. 9. Environmental indicators determining critical levels of damage..

The second workshop focused on a 'Climate Change Mitigation Strategy for Scotland'. Its objectives were to raise awareness of the main issues involved in the development of a Scottish Climate Strategy. The workshop considered actions that might be needed and gathered views from sources regarding the development of a Scottish Climate Strategy. It received expert input from over 70 government organisations, public

companies, research institutes and universities. The subjects discussed were under five headings. These are worth listing, as if acted on they are likely to have an impact on everyone in Scotland in due course, and also to have a potentially large effect on our environment in towns and villages on the one hand and in the countryside on the other.

1. Business.

Fiscal measures to raise investment funds and provide incentives. Regulation and integrated pollution control. Negotiated and voluntary agreements. Emissions trading. Targeted advice and assistance to small and medium enterprises.

2. Energy Supply.

Investment in renewable energy and other non-fossil generation. Combined heat and power. Energy services for customers. Green tariffs. Utility regulation.

3. Households.

Energy efficiency in the home - lights, appliances, central heating, insulation, advice and information. Financial incentives. Local authorities under the Home Energy Conservation Act. Electricity Standards of Performance. Market transformation strategy, appliance suppliers and government.

4. Land use and forestry.

Expansion of woodland areas. Energy crops (biomass). Animal husbandry. Reduced fertiliser use.

5. Transport.

Increasing fuel duties. Voluntary agreements on car efficiency. Alternative fuels, fuel cells, electricity/hybrid vehicles. Best practice techniques for fleet operators. Demand management and model shifts. User charges and traffic management.

The Economy in Scotland

The economy of Scotland will be affected by climate change to different degrees depending on the area of business operation. Transport including the commercial operation of ships, trains, road transport and associated infrastructure will all be affected by climate change. The CCSIS study states that the existing infrastructure for shipping and ferry operations in Scotland is robust. However we doubt this. Past experience shows clearly that major storms in the Firth of Clyde and Firth of Forth would do untold damage. Commercial trains in Scotland will need rolling stock and track updating to take into account the worsening rain and gale predictions. The same is true to an even greater degree for roads, and public and private transport, particularly in the Highlands.

Service industries in Scotland, retail and finance, will be less affected by climate change. This is important, because the service industries contribute two thirds of Scotland's Gross Domestic Product and three quarters of its workforce. The tourism industry is also very important, especially in the Highlands. Clearly warmer climates will mean more tourists unless it is too wet. But rain is not expected to increase in the summer. Winter sports will suffer if snow fall is reduced much below its current level. The short break holiday of two to three days is usually taken in Scottish cities or towns, and so is unlikely to be affected dramatically by climate change unless it is very dramatic.

The Natural Environment in Scotland

The natural environment in Scotland is particularly important for agriculture, forestry and fisheries, and the CCSIS study is aware of and comments on these areas. 'Fishing, forestry and agriculture are valued sources of employment and income in rural parts of Scotland, and are therefore an essential element of a sustainable rural economy'. It identifies salmon and trout as being central to sports fishing for example. It will therefore pay us to consider the potential effects of climate change on each of these three areas in turn.

1. Fisheries and Aquaculture.

The most economically important Scottish based fisheries are the freshwater salmon and sea-trout fisheries in Scottish rivers, loch aquaculture of salmon and to a lesser degree of trout and shell fish, and the fisheries of the North Atlantic and North Sea. Sea trout and salmon catches have fallen significantly during recent years in west coast Scottish rivers. Possible causes are overfishing, pollution, acid run-off from forestry and changes in predator pressure. It is also possible that salmon farming in cages in sea lochs may have had an impact. These farmed salmon may be a source of parasitic sea lice infecting wild fish. They may also cross breed with wild fish.

Climate change is very likely to affect all of the above fisheries, but the precise nature of the effect is difficult to define at present.

Any change in water temperature, salinity and oxygen content will have a significant influence on the fish themselves as well as on their food sources. Changes in ocean currents will also disturb larval behaviour and dispersal. Increased rainfall would interfere with the salmon eggs on river beds, and increase in the number or intensity of storms would affect river flow and certainly reduce the efficiency of marine fishing vessels. A significant increase in water temperature in freshwaters and the sea may lead to faster growth rates in commercial species of fish, but it may also cause southern species to migrate northwards. Southern species may need different fishing methods and equipment, and there are cost implications here.

2. Forestry

Forestry in Scotland is an important industry as identified by the CCSIS report and also has a significant role to play in attracting tourists to the country. There are also major governmental and farming interests involved. The Forestry Commission is responsible for advice to the UK Government on forestry policy and also the implementation of that policy. In July 1999 the Forestry Commission became answerable to the Scottish Executive for most its activities in Scotland. A Scottish Forest Strategy was launched in November 2001 which will "guide the

development of Scotland's expanding forest and woodland area into the 21st century and beyond".

Climate change is most likely to influence Scotland's forests through changes in temperature. Increased temperature usually means an increase in growth rate. However changes in the variation of temperature between summer and winter are also likely to be important. Commercial forestry may benefit by being able to grow a larger number of species than at present if the temperature increases significantly, although this effect will take several decades to be noticeable because of the long growth period of most trees. Increased rainfall will have a significant influence in south east Scotland - where it is relatively dry at present, and major storms are likely to cause wind damage by uprooting trees and also limiting the height of growth in exposed sites. All of these effects of climate change will have an important influence on biodiversity. This is as yet not properly quantified.

3. Agriculture

Agriculture in its broadest sense is practised on almost 80% of land in Scotland, and most of this is grazing by cattle or more frequently sheep as the weather and environmental conditions are do not allow of much else. Profitable farming is difficult because of this, and also because of the long road distances to the industry's main markets. There have been very few studies of the potential influence of climate change on agricultural practice. However it has been suggested that the predicted changes in climate will only have a marginal effect on agriculture at least for the next century. We doubt this, and think that the effects of increased rainfall, more large storms, and increasing temperatures will together have a significant influence during the next 30 years or so. It is certainly true, however, that a longer growing season caused by higher temperatures would tend to increase the diversity of species that can be grown. These would include fodder maize, sugar beet, and oil seed rape.

CONCLUSIONS

There is nothing new about climate change. It is clear from the sedimentary and fossil record that climate change has taken place since the formation of the planet Earth. It has also been a driving force in the whole process of evolution. Historically, records from Scotland and England show that unexpected dry or wet, hot or cold, and windy or calm conditions are phenomena which were common and yet continue to surprise. 1771 AD: 'Dr Johnson says that the season was so severe in the Island of Skye that it is remembered by the name of the Black Spring. The snow, which seldom lies at all, covered the ground for eight weeks, many cattle died, and those that survived were so emaciated that they require no male at the usual season.'. It really must have been quite bad.

Our current increased awareness of the whole process of climate change in all its aspects must surely come from our increased abilities to predict. This predictive ability is based on highly complex modelling scenarios that would not have been possible before the development of computers. The interactive nature of different parts of the environment is also very important. Mountains rivers and the coastal zone all influence each other and in turn are influenced by changing patterns of climate. This is obvious in Scotland. Global warming together with increasing rainfall - especially in the eastern parts of Scotland, means more flooding, rising sea levels and changing patterns of species distribution. Man has much to answer for here. The totally unacceptable annual increase in the production of Greenhouse gases has to be halted. Carbon dioxide from the burning of fossil fuels, and the increasing release of such gases as Methane, Nitrous Oxide, chlorofluorocarbons and hydrochluorofluorocarbons, will eventually set in motion events that cannot easily be reversed. A change in the North Atlantic Drift current, or the collapse of the West Antarctic Ice sheet are examples.

Temperatures are likely to rise 0.5^{o}C to 2.5^{o}C by 2030, which will lead to an average global rise in sea level of 10 cm to 20 cm. This does not sound a great deal, but it will have major impacts on many low lying areas, particularly where land is close to sea level in estuaries around Scotland. Parts of Glasgow and other Scottish cities are also vulnerable. The main problem here is likely to be the onset of storms when tides are very high in Autumn and Spring. To the authors knowledge, there are no contingency plans for major sea level rise in Scotland, although the Scottish Environmental Agency SEPA issues regular flood warnings and advice through its web site and on radio and TV.

A recent study published by the Scottish Executive Central Research Unit 'Climate Change : Scottish Implications Scoping Study' (the CCSIS study) (Kerr, Shackley, Milne, and Allen, 1999) has begun the process of officially addressing the medium and long term implications of global warming for Scotland. The study reports on two important workshops held in 1999, and then goes on to predict the effects of global warming on the Scottish climate and environment, on the economy and business, and on fisheries agriculture and forestry. It is clear that within the next 30 to 50 years everyone will be affected. As a selection, winters will get warmer, the east coast will get wetter, and severe storms will increase in frequency. Southern species of animals and plants will move north, and tourism will be affected by warmer weather with in some areas more rainfall. Transport including the operation of ships, trains and road transport will all be affected by the higher level of rainfall and the increased frequency of severe storms. The freshwater and marine fisheries

of Scotland will almost certainly be affected, although there is not enough information currently available to allow specific predictions. Effects on forestry will include the introduction of new tree species from warmer climates, and the trees themselves becoming shorter - tall ones may well be torn down by high winds. All of these influences are bound to have major and long lasting effects on the biodiversity of natural and farmed land over the coming years. All in all, it is an interesting time to be living in environmentally. Homo sapiens has lived through it before, but been less aware of it. One only has to look at the snow scenes in Dutch 18th century landscape paintings to realise that we have been here before.

REFERENCES

Bakler, T.H. n.d. (In fact c. 1883 - editors). Records of the Seasons, Prices of Agricultural Produce, and Phenomena Observed in the British Isles. Simpkin, Marshall & Co., London.

Batterbury, S., T. Forsyth and K. Thomson (1997) "Environmental transformations in developing countries: hybrid research and democratic policy", *The Journal of Geography*, vol. 163 : 125-132.

Cookson, C. 2002. Turbulent Times. Article. *Financial Times* 17-18th August 2002.

Curran, S. 1998. *Environmental Handbook*. The Stationary Office, London.

Department of the Environment. n.d. (c.1996 - authors). *Global Climate Change*. pp 1-24. 3rd Edtn. Department of the Environment and the Meteorological Office.

Drake, F. 2000. *Global Warming. The Science of Climate Change*. Arnold. London.

Dobby, E.H.G. (1962) *Monsoon Asia. Volume V of a systematic regional geography*. 2nd edition. London : University of London Press.

Farrow, G.E. (2001). James Croll: a 19th Century pioneer of climate change. Glasgow Naturalist, 23, 9-18.

Ford, M.J. 1982. *The Changing Climate.Responses of the Natural Flora and Fauna*. Allen and Unwin. Boston.

Groombridge, B. (ed) (1992) *Global Biodiversity*. London : Chapman & Hall.

Harding, A.F. Ed.) 1982. *Climate Change in Later Pre-history*. Edinburgh University Press. Edinburgh.

Houghton, J.T., L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell (eds) (1996) *Climate change 1995. Contribution of working group I to the second assessment report of the intergovernmental panel on climate change*. Cambridge : Cambridge University Press.

IUCN (1990) *IUCN directory of South Asian protected areas*. Gland, Switzerland and Cambridge, U.K. : IUCN.

Kerr, A. Shackley, S. Milne, & Allen, S. 1999. Climate Change: Scottish Implications Scoping Study. Scottish Executive Central Research Unit.

Kinton, J. 1988. *The Weather of the 1780's over Europe*. Cambridge University Press, Cambridge.

Leggett, J. (Ed.) 1990. *Global Warming. The Greenpeace Report*. Oxford University Press. New York.

Libbe, L.M. 1983. *Past Climates. Tree Thermometers, Commodities, and People*. University of Texas Press. Austin, Texas, U.S.A.

Manley, G. 1975. 1684: the coldest winter in the English instrumental record. Weather 30, 382 - 388.

Meadows, A, & Meadows, P.S. 1999a. Mountains, rivers and coastal zones in Aseia: environmental management and community integration into the 21st century. pp. 49 - 76. In *Integrated Environmental Management. Development, Information, and Education in the Asian-Pacific Region*. Y. Itakura, J.S. Eades, F.M. D'Itri, M. Kawashima, S. Endoh, & H. Kitamura. Lewis Publishers. Boca Raton, U.S.A.

Meadows, A. & P.S. Meadows (eds) (1999b). *The Indus River: Biodiversity, Resources, Humankind*. Karachi : Oxford University Press.

Ribot, J.C., Magalhães, A.R., & Pangides, S.S. (Eds.) 1996. *Climate Variability, Climate Change and Social Vulnerability in the Semi-arid Tropics*. Cambridge University Press. Cambridge.

Shackleton, N.J. West, R.G. & Bowen, D.Q. (Eds.) 1988. *The Past Three Million Years: Evolution of Climatice Variability in the North Atlantic Region*. The Royal Society. London.

Watson, R.T., M.C. Zinyowera and R.H. Moss (eds.) (1996) *Climate change 1995.Impacts, adaptations, and mitigation of climate change: scientific-technical analyses*. Cambridge : Cambridge University Press.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 23-28.

COMMUNITY STRUCTURE AND BIOMETRICS IN MICROHABITATIS WITHIN MUSSEL BEDS (*MYTILUS EDULIS*) FROM INTERTIDAL ENVIRONMENTS AT ARDMORE BAY, CLYDE ESTUARY, SCOTLAND.

Noelia Carrasco, Azra Meadows, and Peter S. Meadows

Biosedimentology Unit, Graham Kerr Building, Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, University of Glasgow, G12 8QQ.

ABSTRACT

The edible mussel, *Mytilus edulis*, is very common in the Firth of Clyde and Clyde Estuary, Scotland, living intertidally on rocks and mud where it often forms extensive beds. The beds are bound together by byssus threads secreted by the species. Two packing structures occur in the beds and provide microhabitats for other invertebrate species. These are towers of mussels forming upwards from the general bed to 20 cm, and the rings of mussels forming on the surface of the sediment at the edge of beds. Samples (clumps of mussels) from the towers and rings at an exposed and a sheltered site at Ardmore Bay, Clyde Estuary were collected and analysed in two ways.

Firstly, biometric data of the mussels (length, breadth, wet weight) in the samples were recorded. There were no differences between the biometry of the mussels in the towers and rings, or between the sheltered and exposed sites, except that the mussels at the exposed site were slightly broader. This suggests a greater tissue weight, which may be caused by more abundant food, at the exposed site.

Secondly, the number of species and number of individuals/species of invertebrates in the sampled clumps of mussels were recorded. Sixteen species were recorded, belonging to the crustaceans, the annelid polychaetes and oligochaetes, and the molluscan bivalves and gastropods. When found outside the mussel clumps, these species are either infaunal, epifaunal, or surface dwelling species able to migrate into the overlying water. This suggests that the mussel clumps provide an unusual mix of microhabitats.

Cluster analysis was used to cluster the towers and rings at the exposed and sheltered sites, and to cluster the species. There was a tight clustering of the rings and towers with much less significant clustering of the exposed and sheltered sites. There was no obvious ecological clustering of species by similarity of habitat, but there was an unexpected taxonomic clustering of the molluscan species.

The results are discussed in terms of the microhabitats that may exist within the towers and rings, and the need for a comparison of these with microhabitats where the invertebrate species are more usually found. These latter include intertidal sedimentary and rocky environments.

INTRODUCTION

The coastal zone is an area of dynamic change and spatial heterogeneity. This is particularly marked in the intertidal zone where sedimentary environments are alternately exposed to air and water as the tide falls and rises. Wind, water currents, changes of salinity and fresh water flux, also produce temporal and spatial heterogeneity. This heterogeneity then imposes temporal and spatial heterogeneity on the distribution and abundance of intertidal species. The intertidal zone, therefore, is one that offers a unique opportunity to investigate the some of the central questions in marine ecology about the presence of and factors governing spatial and temporal heterogeneity at different scales (Reise, 1985; Tufail et al., 1989; Meadows et al., 1998; Armonies & Reise, 2000). The west coast of Scotland is particularly rich important here in terms of the range and diversity of intertidal habitats, and it contains some of the finest examples of rocky, sandy and muddy shores in Europe.

Spatial heterogeneity is everywhere on these intertidal shores (Meadows & Anderson, 1978). Typical examples are the vertical zonation of organisms on rocky shores, the biodiversity of rock pools, and the different localised communities associated with muddy and sandy shores. Sometimes organisms themselves provide a substrate or habitat for different communities. These are of special interest because they provide examples of animals and plants interacting with other animals and plants in the intertidal zone to produce spatial heterogeneity, rather than distributional heterogeneity being controlled mainly by physical and chemical parameters in the intertidal zone (Fenchel & Reidl, 1970; Anderson & Meadows, 1978; Mckindsay & Bourget, 2000; McQuaid et al., 2000). Well known examples include species of tube worm, such as *Spirorbis borealis* and *Spirorbis spirillum* living on selected species of seaweeds, and the red seaweed *Polysiphonia lanosa* living on the bladder wrack, *Ascophyllum nodosum*. Mussel beds formed by the edible mussel *Mytilus edulis* (Field 1922; White, 1937; Theisen, 1968; Mason, 1976) also offer habitats for many species of rock dwelling and sedimentary organisms and these are common in the Clyde estuary and Clyde Sea area. This paper is concerned with the biodiversity of unusual structures formed in some of these beds in the Clyde Estuary by clumps of mussels.

Mytilus edulis is a common intertidal species in the Clyde. It occurs naturally here and elsewhere from mid-tide level into the shallow sublittoral, on rocky sandy and muddy substrates, and often forms dense beds (Scott, 1896; Maas Gesteranus, 1942; Kuenen, 1942; Verwey, 1952; Theisen, 1968; Mason, 1976 Hayward 1986). The beds consist of complex multilayered structures produced by the mussels, with density-dependent effects on survival, growth and self-thinning (Meadows & Shand, 1989; Guinez and Castilla 1999). The whole structure is

bound together by byssus threads produced by the mussels themselves.

We have often observed two characteristically different packing structures of mussels in the beds. The first are towers of mussels forming upwards from the general level of the bed to a height of about 20 cm. The second are rings of mussels that sometimes form on the surface of the sediment at the edge of a bed. The present study, conducted at Ardmore Bay in the Clyde Estuary, compares the biometry of the mussels in the towers and rings, and the biodiversity of the benthic infauna within the towers and rings. Comparisons are made on towers and rings from two sites - a sheltered part of the bay and an exposed part of the bay.

MATERIALS AND METHODS

The study site was a bay at Ardmore Point in the Clyde Estuary (latitude 55° 58' 32" N. Longitude 4° 41' 29" W) (British National Grid Reference NS322792) (Meadows et al.1998). Ardmore Point is a S.S.I. (Sites of Special Scientific Interest) and a Coastal Nature Reserve (Boyd 1986).

The field sampling was undertaken during October, November and December 1999 and the frequency of sampling was once a week. Samples were collected at approximately the time of low tide. Two sampling sites were established, an exposed site on the southerly headland of the bay and a sheltered site within the bay on its north-westerly side. Samples consisting of clumps of mussels from towers and rings were taken at the two sites, which were then transported to the laboratory.

Two laboratory investigations were conducted on the samples. The first was a biometric study of the length, width, whole weight and shell weight of 30 mussels from the towers and rings at the sheltered and exposed site. Hence 120 mussels in total were measured. This was analysed by ANOVA.

The second study consisted of an investigation of the biodiversity of benthic infaunal invertebrates within towers and rings at the exposed and sheltered sites. This involved isolating the invertebrates from the mussel clumps, and then identifying and counting the number of individuals in each species. Cluster analyses were also conducted on the data. This was done in two ways. Firstly, the towers and rings from the exposed and sheltered sites were used to cluster the species. Secondly, the species were used to cluster the towers and rings at the sheltered and exposed sites. In both cases the data used were the abundance of the species in the towers and rings at the exposed and sheltered sites.

RESULTS

Biometric analysis of Mytilus edulis in towers and rings from the exposed site and the sheltered site.

Statistical analyses by ANOVA of the biometric measurements of *Mytilus edulis* length, width, and wet weight gave the following results. There was no significant difference in the length, width and wet weight of the mussels between towers and rings at the exposed site and between towers and rings at the sheltered site. There was also no difference between the towers at the sheltered site and the towers at the exposed site, and between the rings at the sheltered site and the rings at the exposed site. There was one statistically significant difference. The length/width ratio of *Mytilus edulis* forming rings at the exposed site was lower than at the sheltered site (F: 9.246; $0.005>P>0.001$; D.F: 1).

Community structure of benthic infauna within towers and rings at the exposed and sheltered site.

Benthic infaunal invertebrates

Table 1 gives a list of the benthic infauna found within the towers and rings at the exposed and sheltered sites. Sixteen species were found in the towers and rings, of which seven species are molluscs including four species of *Littorina*, five species are crustacea, three species are polychaetes, and one species is an oligochaete annelid. All the species of molluscs, polychaetes and the annelid are true benthic forms (Table 1). Six of these benthic species are normally considered as infaunal burrowing organisms that either plough through the sediment or construct tubes or burrows within it (Table 1, species labelled A). The species labelled B in table 1 are all epifaunal species which in a normal sedimentary environment live at the sediment-water interface. The species labelled C in table 1 are all crustacea. These latter species, although living on the sea bed either on sediments on rocks or under stones, are able to make excursions into the overlying water column when covered by the tide.

Clustering of rings and towers at the exposed and sheltered sites, and clustering of benthic infaunal invertebrates.

The clustering of rings and towers, and of the benthic infaunal invertebrates is shown in table 1.

The lower cluster diagram in figure 1 shows the clustering of the towers and rings and the exposed and sheltered sites. There are three distinct clusters (Figure 1, lower cluster diagram, clusters 1,2, and 3). The clustering indicates that the towers and rings are clustered more than are the sheltered and exposed sites when assessed by the numbers of individuals in the different species living in them. Cluster one contains seven towers and one ring, distributed equally between four exposed sites and four sheltered sites. It can therefore be considered as a tower cluster. Cluster two contains seven rings, five of which are from sheltered sites and two from exposed sites. This cluster can therefore be considered as a ring cluster made up largely of rings in sheltered sites. Cluster three, an outlying cluster, contains two towers both from sheltered sites.

The upper cluster diagram in figure 1 shows the clustering of the sixteen benthic invertebrates (table 1) isolated from the towers and rings at the exposed and sheltered sites. There are two major clusters (Figure 1, upper cluster diagram, clusters 1 and 2), the first cluster being divided into two smaller clusters (3 and 4 in figure 1), and the second containing a smaller subcluster (5 in figure 1). These clusters are derived from, and hence

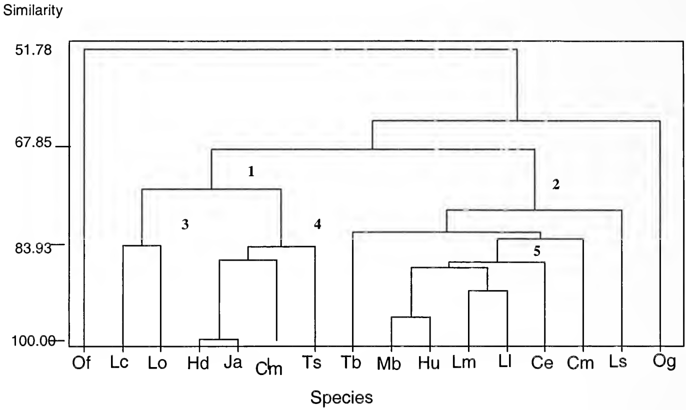
Table 1. List of invertebrate species found in towers and rings of *Mytilus edulis* at the exposed and sheltered sites, showing their taxonomic group and habitat. Common names given after scientific names, where known. Normal Habitat = usual habitat that the species is found in, defined thus: **A**, infaunal benthic invertebrates that either plough through the sediment or construct burrows or tubes in it; **B**, epifaunal benthic invertebrates that live at the sediment/water interface; **C**, benthic invertebrates that live on the surface of rocks or sediments, and make regular forays into the overlying water.

Species	Taxonomic Group	Normal Habitat
Carcinus maenas (Lineaus) Common shore crab.	Crustacea	C
**Cerastoderma edulis (Linneaus) Edible cockle.	Mollusca, Bivalvia	A
Chaetogammarus marinus Leach	Crustacea	C
***Hediste (Nereis) diversicolor* (O.F.Müller) Rag Worm	Annelida, Polychaeta	A
**Hydrobia ulvae* (Pennant) Laver Spire Shell	Mollusca, Gastropoda	B
Jaera albifrons Leach	Crustacea	C
***Lanice conchilega* (Pallas) Sand Mason	Annelida, Polychaeta	A
**Littorina littorea* (Linneaus) Edible Periwinkle	Mollusca, Gastropoda	B
**Littorina mariae* Sacchi and Rastelli	Mollusca, Gastropoda	B
**Littorina obtusata* (Linneaus) Flat Periwinkle	Mollusca, Gastropoda	B
**Littorina saxatilis* (Olivi) Rough Periwinkle	Mollusca, Gastropoda	B
***Macoma balthica* (Linneaus) Baltic Tellin	Mollusca, Bivalvia	A
Orchestia gammarellus (Pallas)	Crustacea	C
***Owenia fusiformis* (Delle Chiaje)	Annelida, Polychaeta	A
Talitrus saltator (Montagu) Sand Hopper	Crustacea	C
***Tubificoides* spp.	Annelida, Oligochaeta	A

measured by, the towers and rings and at the exposed and sheltered sites. A careful inspection of the species making up the different clusters shows little commonality amongst the species within each cluster. There is a random distribution between the clusters of the infaunal and epifaunal species and the species that migrate into the water column (Table 1, species labelled A, B, and C)

The clustering is therefore not based on infaunal or epifaunal species ecological requirements. There is some indication of a taxonomic clustering. Cluster two contains seven molluscan and one crustacean species. Within cluster two, subcluster five contains five molluscan species and one crustacean species. So both cluster two and cluster five within it can be considered molluscan clusters. However cluster one is very mixed taxonomically, containing three species of crustacea, two species of polychaetes, and one species of mollusc. Subclusters three and four within cluster one are also taxonomically mixed.

There are two pairs of species that cluster at a very high similarity, and therefore are very closely related in terms of their distribution and abundance between the towers and rings at the exposed and sheltered sites. The first pair consists of the two infaunal molluscs *Macoma balthica* and *Hydrobia ulvae* in cluster 2 and subcluster 5. The second pair consists of two very disparate species, the polychaete *Hediste diversicolor* and the isopod crustacean *Jaera albifrons*.



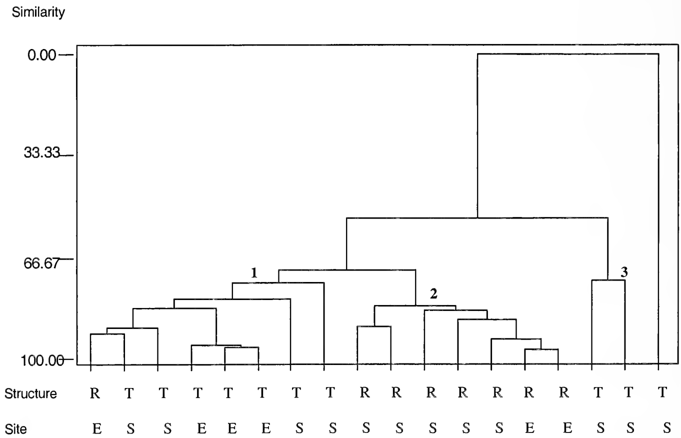


Figure 1. TOP CLUSTER DIAGRAM species. **Of** *Owenia fusiformis*, **Lc** *Lanica conchilega*, **Lo** *Littorina obtusata*, **Hd** *Hediste(Neries) diversicolor*, **Ja** *Jaera albifrons*, **Cm** *Chaetogammarus marinus*, **Ts** *Talitrus saltator*, **Tb** *Tubificoides ben*
Mb *Macoma balthica*, **Hu** *Hydrobia ulvae*, **Lm** *Littorina mariae*, **Ll** *Littorina littorea*, **Ce** *Cerastoderma edulis*, **Cm** *Carcinus maenas*, **Ls** *Littorina saxatilis*, **Og** *Orchestia gammarellus*.
Figure 1. BOTTOM CLUSTER DIAGRAM. Structure (**R** rings and **T** towers), and site (**S** sheltered and **E** exposed)

DISCUSSION

There are three aspects of the results reported in this paper that require comment. The first concerns the relative biometries of the mussels collected from the towers and rings at the exposed and sheltered sites. The second concerns the ecological and biological characteristics of the invertebrates found in the towers and rings. The third concerns possible interpretations of the clusters that are shown by the towers and rings and the exposed and sheltered sites, and of the clusters that are shown by the invertebrate species found within the towers and rings. We will consider these in turn.

The biometric measurements taken on *Mytilus edulis* consisted of length, width, and wet weight. The towers and rings exist in different microenvironments, and the exposed and sheltered environments have very different energy regimes in terms of wave power. One might expect, therefore, that factors determining length, width and wet weight might vary considerably between these environments. This does not appear to be the case however, as there were no statistically significant differences in the biometric parameters between *Mytilus edulis* collected from the towers and rings at the exposed and sheltered sites. There was only one exception to this. The length/width ratio was lower in *Mytilus edulis* from the rings collected at the exposed site than in *Mytilus edulis* collected from rings at the sheltered site. This means that at the exposed site the shell of *Mytilus edulis* was significantly wider when compared with its length than at the sheltered site. In other words, the shells of *Mytilus edulis* at the exposed site are broader in relation to their length than those at the sheltered site. This implies that the soft parts of the body are larger in the rings at the exposed site. It is possible that this may be associated with a higher food supply and hence energy in terms of the planktonic and detrital material that *Mytilus edulis* filters and uses as a food source. However it does beg the question as to why the same effect was not apparent between *Mytilus edulis* from the towers at the exposed site when compared with the towers at the sheltered site.

The ecology of the sixteen species of benthic invertebrates found in the towers and rings formed by *Mytilus edulis* at the exposed and sheltered sites are interesting (Table 1). They are a mixture of infaunal species, epifaunal species and species that are known to move between the seabed and the overlying water column when covered by the tide. The presence of such a wide range of invertebrates within the towers and rings shows that the microhabitat provided by the towers and rings is an interesting one. It is clearly suitable for species that normally live in very different local environments. The towers and rings may have biological, physical and chemical properties that provide a mixture of characteristics shown by the water column, the sediment/water interface, and the surficial sedimentary column below the sediment/water interface. It would be interesting to know what these characteristics are, and to compare them in detail with the same characteristics within mussel beds proper, and with the three more usual habitats. They may include differential water circulation within the towers and rings, localised trapping of sediment, localised differences in redox potential, and changing predator/prey relationships. We suggest, therefore, that microscale variation in habitats might explain the diverse range if invertebrate species found in the towers and rings. In this context would be interesting to compare the overall biodiversity and species composition of invertebrates living in mussel beds with those of the ring and tower structures, and to dissect microscale differences in biodiversity and species composition within single rings and single towers.

The clustering of the towers and rings at the exposed and sheltered sites, and of the invertebrate species found in these structures (Figure 1), provides some insight into the ecological phenomena and species interactions and that occur there. It also raises some questions. The cluster analysis is based on a two dimensional matrix of data, consisting of the numbers of individuals in each species in each tower and each ring at the exposed and sheltered sites. The row headings of the matrix are the species, and the column headings are successive towers and rings that have been sampled at the exposed and sheltered sites. The numbers in the body of the matrix are the numbers of individuals in each species. Firstly the species were used to group and hence cluster the towers and rings and the exposed and sheltered sites. This produced the bottom cluster diagram in figure 1. Then the towers and rings at the exposed and sheltered sites were used to group and hence cluster the individual species. This produced the top cluster diagram in figure 1.

The clustering of the towers and rings and the exposed and sheltered sites shown in the bottom cluster diagram in figure 1 indicates a tight grouping of the rings and towers by the abundance of the individual species, with much less influence on the clustering of the exposed and sheltered sites. Specifically, cluster one is a tower cluster and cluster two is a ring cluster (Figure 1, bottom cluster diagram). Hence the relative abundance of the species is correlated closely with and accurately distinguishes between the towers and the rings. This is not so of the exposed and sheltered sites. It is not clear why this difference should be so. One can only conclude – following the argument outlined above, that the micro-environments within the towers are significantly different from the micro environments within the rings, and that these are appreciably greater than any differences imposed on the data by the exposed and the sheltered site – at least as far as the invertebrate species inhabiting them are concerned. A comparison the environmental parameters governing the characteristics of the microhabitats within the towers and within the rings would be very worthwhile.

The clustering of the sixteen species (Figure 1 upper cluster diagram) is more difficult to interpret. There is no obvious ecological clustering of species by similarity of habitat (Table 1). The random distribution between the clusters of the infaunal and epifaunal species and of the species that migrate into the water column, is puzzling. This random distribution is emphasised by the unexpected taxonomic clustering. Here, cluster two and subcluster five (Figure 1 upper cluster diagram) are almost entirely made up of molluscs. There is no obvious explanation of this taxonomic clustering, and it becomes more inexplicable in view of the lack of taxonomic similarity in cluster one and subclusters three and four (Figure 1 upper cluster diagram), which contain crustacean, polychaete and mollusc species.

Two pairs of species, *Macoma balthica* and *Hydrobia ulvae* (within subcluster 4, figure 1 upper cluster diagram), and *Hediste diversicolor* and *Jaera albifrons* (within subcluster 5, figure 1 upper cluster diagram) require comment. In both cases the pairs cluster at very high similarity levels. The first pair, *Macoma balthica* and *Hydrobia ulvae*, are both molluscs, and both are deposit feeders. In a normal sedimentary environment *Macoma balthica* lives just below the sediment/water interface and *Hydrobia ulvae* lives at the sediment/water interface. Both are found at Ardmore Bay in the same part of the upper intertidal sedimentary ecosystem, co-existing in essentially the same habitat. There is considerable similarity, therefore, between their usually observed ecological niches on the shore.

The second pair contains two very disparate species taxonomically and ecologically, consisting of the polychaete *Hediste diversicolor* and the isopod crustacean *Jaera albifrons*. *Jaera albifrons* is normally recorded from the upper intertidal region in estuaries, and lives under stones. It is not a species that is normally associated with sedimentary ecosystems, and our own field observations suggest that it is not particularly common at Ardmore Bay.

On the other hand, *Hediste diversicolor* is an infaunal polychaete very characteristic of muddy sediments in estuaries, where it constructs burrows to a depth of 10 cm or more. This species is very common at Ardmore Bay. Clearly, the towers and rings at the exposed and sheltered sites have between them have combinations of characteristics that are specifically required by both pairs of species in different ways.

We have no indication of the ecological microhabitats within the towers and rings and how they might select these two pairs of species. It is particularly interesting because the first pair of species are closely related in an ecological sense, while the exact opposite is true of the second pair of species. Here again, further investigation of their microhabitats within the towers and rings would be very worthwhile.

REFERENCES

Anderson, J.G. & Meadows, P.S. 1978. Microenvironments in marine sediments. *Proceedings of the Royal Society of Edinburgh* 76B 1-16.

Armonies, W. & Reise, K., 2000. Faunal diversity across a sandy shore. *Marine Ecology Progress Series*, 196, 49-57.

Fenchel, T. & Reidl, R,J, 1970. The sulphide system: a new biotic community underneath the oxidised layer of marine sandy sediments. *Marine Biology*, 7, 255-268.

Field, J.A. 1922. Biology and economic importance of the seal mussel, *Mytilus edulis*. *Bulletin of the Bureau of Fisheries, Washington* 38, 127-260.

Guinez, R & Castilla, J.C. 1999. A tridimensional self-thinning model for multilayered intertidal mussels. *American Naturalist* 154, 341-457.

Kuenen, D.J. 1942. On the distribution of mussels on the intertidal sand flats near Den Helder. *Archs neerl Zool* 6, 8-158.

Mason, J. 1976. Cultivation. Pp 385-410. In Bayne, B.L. (ed). *Marine Mussels*. Cambridge University Press. Cambridge UK.

Maas Gesteranus, R.A. 1942. On the formation of banks by Mytilus edulis. L. *Archs neerl Zool*, 6 283-326.

Mckindsay, C.W. & Bourget, E. 2000. Explaining mesoscale variation in intertidal mussel community structure. *Marine Ecology Progress Series*, 205, 155-170.

McQuaid, C.D., Linsay, J.R. & Linsay T.L. 2000. Interactive effects of wave exposure and tidal height on population structure of the mussel Perna perna. *Marine Biology*, 137, 925-932.

Meadows, A., Meadows, P.S., & McLaughlin, P. 1998. Spatial heterogeneity in an intertidal sedimentary environment and its macrobenthic community. In: Black, K.S., Paterson, D.M. & Cramp, A. (eds) *Sedimentary Processes in the Intertidal Zone, Geological Society, London, Special Publications* 139, 367-388.

Meadows, A., & Shand, P. 1989. Experimental analysis of byssus thread production by *Mytilus edulis* and *Modiolus modiolus* in sediments. *Marine Biology*, 101, 219-226.

Reise, K., 1985. *Tidal Flat Ecology. An Experimental Approach to Species Interactions*, Springer-Verlag. Berlin

Theisen, B.F. 1968. Growth and mortality of culture mussels in the Danish Wadden Sea. *Meddr Danm Fisk. –og. Havunders. (N.S.)* 6: 47-78.

Scott, A. 1896. Mussels and mussel beds. *Reports of the Lancashire Sea-Fishery Laboratories*, 58-87.

Tufail, A., Meadows, P.S. & McLaughlin, P. 1989. Meso- and micro-scale heterogeneity in benthic community structure and the sedimentary environment on an intertidal muddy-sand beach . Proceedings of the *22nd European Marine Biology Symposium*, Barcelona. *Scientia Marina* 53: 319-327.

Verwey, J. 1952. On the ecology of distribution of cockle and mussel in the Dutch Waddensea, their role in sedimentation and source of their food supply. *Archs Neerl Zool*. 10, 171-239.

White, K.M. 1937. *Mytilus*. *L.M.B.C.Memoir*.3, 1-177.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 29-33.

SCOTTISH INSECT RECORDS FOR 2001

Compiled by E.G. Hancock
Zoology Museum, Graham Kerr Building, University of Glasgow, Glasgow, G12 8QQ.

INTRODUCTION

The aim of these compilations, begun by Christie (1984), is to bring together records of interest that have come to the attention of field workers active in Scotland during each year. In the list, specific names of Lepidoptera and the reference numbers are as in Bradley (1998). As these entries are numbered, following the well-established system initiated by Bradley & Fletcher (1979) family names have been omitted. The new check list of the British Diptera (Chandler, 1998) has been used for that order. Other orders of insects follow the names that are given in Kloet & Hincks (1964, 1977, 1978) with some recent additions and amendments.

Much of Scotland still lacks basic faunistic information in its more isolated parts for insects that may elsewhere be unremarkable and so not only 'rare' species are treated.

ODONATA

LIBELLULIDAE

Sympetrum striolatum (Charpentier). Common darter. SWT Falls of Clyde reserve, South Lanarkshire, male and female in tandem settled on post of pond-dipping platform (NS882425), Vc77, 01/8/01, SWG.

HEMIPTERA

CIMICIDAE

Cimex lectularius L. Bedbug. In tenement flat, Dumbarton Rd, Glasgow, examples with different instars sent in by local General Practioner (NS5566), Vc77, 1/3/01, EGH.

LEPIDOPTERA

15 *Hepialus sylvina* (L.). Orange swift. Lynachlaggan, Insh Marshes, Kingussie, Inverness-shire, mv trap in birchwood (NH817017), Vc96, 28/07/01, TB.

18 *H. fusconebulosa* (DeGeer). Map-winged swift. Dumbarton, in garden (NS386752) Vc99, 1/7/01, K&SF.

56 *Stigmella dryadella* (Hofmann). Caenlochan Crags, mines in *Dryas* (NO1776), Vc90, 27/7/01, KPB. New vice county record.

64 *S. continuella* (Stainton). Allt Conait Gorge, single mine on birch, *Betula pendula* (NN5146), Vc88, 9/8/01, JC.

145 *Nemophora minimella* (Denis & Schiffermüller). Tailend Moss, adult swept (NT0067), Vc84, 15/7/01, KPB. New to vice county.

154 *Heliozela sericella* (Haworth). Riechip, mine in oak (NO0647), Vc89, 22/9/01, KPB. New to vice county.

169 *Zygaena filipendulae* (L.). Six-spot burnet. Ailsa Craig (NX0199), Vc75, 8/8/01, BZ.

257 *Leucoptera orobi* (Stainton). Isle of Rum, mines in *Trifolium pratense* (NG3900), Vc104, 31/8/00, KPB. The adult emerged this year from mines collected in 2000 and it is included as being new to the vice county.

285 *Caloptilia azaleella* (Brants). Blackford, adult to light (NT2571), Vc83, 1-2/7/01, KPB. New to vice county.

409a *Argyresthia trifasciata* Staudinger. Broughty Ferry, Dundee, adults by day (NO4631), Vc90, 24/6/01 & 15/7/01, JC.

564 *Coleophora obscenella* Herrich-Schäfer. Bemersyde Hill, cases on *Solidago* (NT5934), Vc81, 27/10/01, KPB. New to vice county.

722 *Ethmia pyrausta* (Pallas). The Cairnwell, adult at 810m. alt. (NO1278), Vc92, 28/5/01, KPB. New to vice county.

784 *Bryotropha galbanella* (Zeller). Adderstone Moss, adult on wing (NT5312), Vc80, 2/7/01, KPB. New to vice county.

789 *B. domestica* (Haworth). Arthur's Seat, Edinburgh, larvae reared from moss (NT2773), Vc83, 17/2/01, KPB. New to vice county.

822 *Scrobipalpa acuminatella* (Sircom). Dunhog Hill, larvae in *Cirsium palustre* (NT4624), Vc80, 1/7/01, KPB. New to vice county.

874 *Blastobasis decolorella* (Wollaston). Stenton, adults collected (NT6274), Vc82, 28/5/01, AEW (det. KPB). New to vice county.

884 *Mompha miscella* (Denis & Schiffermüller). St Mary's Loch, mines in rockrose (NT2423), Vc79, 26/5/01, KPB. New to vice county.

896 *Cosmopteryx orichalcea* Stainton. Isle of Rum, reared from mines in *Anthoxanthum* (NG3503 & NM4099), Vc104, 27-30/8/00, KPB. This record is confirmed as a Scottish resident by this rearing record, emerging from larvae collected in the previous year.

898 *Limnaecia phragmitella* Stainton. Duddingston Loch, infesting *Typha* heads (NT2872), Vc83, 4/7/01; Uphall, in *Typha* heads (NT0670), Vc84, 9/6/01, KPB. New to vice county.

985 *Cacoecimorpha pronubana* (Hübner). Dumbarton, in garden (NS386752) Vc99, 5/8/01, K&SF. An introduced species well established in the south of Britain and spreading slowly into the north of England. It was found as a pupa attached to a *Buddleia davidii* purchased from a local garden centre. New record for Scotland.

998 *Epiphyas postvittana* (Walker). Broughty Ferry, Dundee, at light (NO4631), Vc90, 10/6/01, JC. An introduced species, originally native to Australia and spreading throughout Britain. This appears to be the first Scottish record.

1030 *Eana incanana* (Stephens). Killiecrankie Wood, to light (NN9161), Vc88, 14/7/01 & 3/8/01; Ardrostan Wood, at light (NN6923), Vc88, 10/7/01, JC.

1130 *Epinotia pygmaeana* (Hübner). Mincrieffe Hill, one adult (NO1319), Vc88, 12/5/01, KPB. New to vice county.

1316 *Catoptria falsella* (Denis & Schiffermüller). Killiecrankie Wood, to light (NN9161), Vc88, 13/8/01, JC.

1428 *Aphomia sociella* (L.). Bee moth. Dumbarton, in garden (NS386752) Vc99, 31/7/01, K&SF.

1551 *Pieris napi* (L.). Green-veined white. Ailsa Craig, male and female seen (NX0199), Vc75, 8/8/01, BZ.

1553 *Anthocharis cardamines* (L.). Orange tip. Carnasserie Farm, Loch Fraphorm (NM8304), Vc98, 6/5/01, RC; nr Oban (NM890300); Glen Lonan (NM9128), Vc98, 12/5/01, JPB; SWT Falls of Clyde reserve, South Lanarkshire, nectaring on cuckoo flower (NS882425), Vc77, 08/05/01, SWG.

1555 *Callophrys rubi* (L.). Green hairstreak. South end of Shuna (NM70), Vc98, 13/5/01, DH; road to Sherrifmuir Inn (NN8202), Vc87, 2001, DB; Uplandway, Helensburgh (NS299840), Vc99, 13/5/01 K&SF; Pappert Muir (NS412802), Vc99, 20/5/01, JM.

1597 *Inachis io* (L.). Peacock. Falls of Clyde reserve, South Lanarkshire, nectaring on daisies and dandelion (NS882425), Vc77, 1/5/01, SWG; Moy Castle, Mull (NM599247), Vc103, 11/5/01, D&AW; Glasdrum (NN001454), Vc98, 12/5/01, JPB; Craigens, Loch Gruinart, Islay (NR294667), Vc102, 22/12/01, LK; King's Cave, Arran (NR884310) Vc100, 18/9/01, RT; on A841 roadside, Arran, adults and larvae (NR898313), Vc100, 2/7/01, GW; Fallen Rocks, Laggan, Arran (NR9850, NR9949 & NS0048), Vc100, 28/8/01, RT; Dunchraigaig Cairn (NR9783), Vc98, 31/5/01, RD.

1607 *Argynnis aglaja* (L.). Dark green fritillary. South Kiloran Bay (NR3998); track to Balnahard Bay, Colonsay (NR4098), Vc102, 14/7/01, DB.

1614 *Pararge aegeria* (L.). Speckled wood. Machrie Moor road, Arran (NR9133), Vc100, 22/7/01; fallen Rocks, Laggan, Arran (NR9949) Vc100, 28/8/01, RT.

1618 *Erebia aethiops* (Esper). Scotch argus. Loch Fyne smokehouse (NN1812). Vc98, 27/7/01, AH; Loch Sloy (NN277089-287089), Vc99, 2001, JM; Daer Reservoir (NS9702), Vc77, 9/7/01, JW; Ailsa Craig, details to be published separately (NX0199), Vc75, 8/8/01, BZ.

1626 *Maniola jurtina*. (L.). Meadow brown. SWT Falls of Clyde reserve, South Lanarkshire. Netted in long grass in overgrown meadow. (NS882425), Vc77, 15/08/01, SWG.

1628 *Coenonympha tullia* (Müller). Large heath. Reservoir at Scalasaig Hotel, Colonsay (NR3894) Vc102, 12/7/01, DB.

1629 *Aphantopus hyperantus* (L.). Ringlet. Waste ground at Airdrie Road, Carluke (NS844510), Vc77, 2-7/7/01, EY; near Forth (NS911554), Vc77, 3/9/01, DM ; Daer Reservoir (NS9708) Vc77, 29/07/01, JW; SWT Falls of Clyde reserve, South Lanarkshire, netted in long grass in overgrown meadow (NS882425), Vc77, 02/07/01, SWG; Balloch Park, Dumbarton (NS390836), Vc99, 2/7/01, K&SF.

1722 *Xanthorhoe designata* (Hufnagel). Flame carpet. SWT Falls of Clyde reserve, South Lanarkshire, netted flying over dense vegetation in woodland (NS882425), Vc77, 01/8/01, SWG.

1732 *Scotopteryx chenopodiata* (Linnaeus). Shaded broad-bar. SWT Falls of Clyde reserve, South Lanarkshire, netted flying over dense vegetation in woodland (NS882425), Vc77, 01/8/01, SWG.

1770 *Thera cognata* (Thunberg). Chestnut-coloured carpet. Insh Marshes, Kingussie, Inverness-shire, mv trap in birchwood (NH817017), Vc96, 28/07/01, TB. Red Data Book status 'Notable B'.

1801 *Perizoma taeniata* (Stephens). Barred carpet. Killiecrankie Wood, to light (NN9161), Vc88, 13/8/01, JC.

1866 *Carsia sororiata* (Hübner). Manchester treble-bar. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 28/07/01, TB. Red Data Book status 'Notable B'.

1870 *Odezia atrata* (L.). Chimney sweeper. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 5/07/01, TB; SWT Falls of Clyde reserve, South Lanarkshire, netted in long grass in overgrown meadow. (NS882425), Vc77, 20/6/01, SWG; Balloch Park, Dumbarton, over 1000 individuals flying together (NS388833), Vc99, 2/7/01, K&SF.

1874 *Euchoeca nebulata* (Scopoli). Dingy shell. Ardrostan Wood, at light (NN6923), Vc88, 10/7/01, JC.

1941 *Alcis repandata* (Linnaeus). Mottled beauty. SWT Falls of Clyde reserve, South Lanarkshire, netted flying over dense vegetation in woodland (NS882425), Vc77, 01/8/01, SWG.

1991 *Deilephila elpenor* (L.). Elephant hawkmoth. Craigmarloch, North Lanarkshire, attracted to house light (NS739757), Vc77, 06/07/01, SWG.

1995 *Cerura vinula* (L.). Puss moth. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 5/07/01, TB.

2103 *Eugnorisma depuncta* (L.). Plain clay. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 28/07/01, TB; Killiecrankie Wood, to light (NN9161), Vc88, 13/8/01 & 6/9/01, JC. Red Data Book status 'Notable B'.

2116 *Paradiarsia sobrina* (Duponchel). Cousin German. Insh Marshes, Kingussie, Inverness-shire, MV trap, herb-rich meadow (NN787996), Vc96, 28/07/01, TB. Red Data Book status 'Notable A' (BAP prority).

2137 *Eurois occulta* (L.). Great brocade. Lynachlaggan, Insh Marshes, Kingussie, Inverness-shire MV trap in birchwood (NH817017), Vc96, 17/07/01, TB. Red Data Book status 'Notable A'.

2138 *Anaplectoides prasina* (Denis & Schiffermüller). Green Arches. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 25/07/01, TB.

2150 *Polia nebulosa* (Hufnagel). Grey arches. Killiecrankie Wood, to light (NN9161), Vc88, 3/8/01, JC.

2162 *Papestra biren* (Goeze). Glaucous shears. Blackhill Mire, Helensburgh (NS307837), Vc99, 20/5/01, K&SF.

2216 *Cucullia umbratica* (L.). Shark. Dumbarton, in garden (NS386752) Vc99, 30/6/01, K&SF.

2248 *Dryobotodes eremita* (Fabr.). Brindled green. Killiecrankie Wood, to light (NN9161), Vc88, 13/8/01, JC.

2313 *Enargia paleacea* (Esper). Angle-striped sallow. Killiecrankie Wood, to light (NN9161), Vc88, 1/9/01, JC.

2440 *Plusia putnami gracilis* (Lempke). Lempke's gold spot. Insh Marshes, Kingussie, Inverness-shire, mv trap, herb-rich meadow (NN787996), Vc96, 28/07/01, TB.

HYMENOPTERA

SIRICIDAE

Urocerus gigas (L.). Giant wood wasp. SWT Falls of Clyde reserve, South Lanarkshire, adult caught in spiders web on stonework of the SWT Visitor Centre (NS882425), Vc77, 15/8/01, SWG.

COLEOPTERA

CARABIDAE

Carabus glabratus Paykull. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

C. problematicus Herbst. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

C. violaceus L. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

Nebria salina Fairmaire & Laboulbène. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

N. rufescens (Ström) (= *gyllenhali* (Schroeder). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

Notiophilus aquaticus (L.). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

N. biguttatus (Fabr.). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

N. germinyi Fauvel. Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

Clivina fossor (L.). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

Trechus obtusus Erichson. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

Patrobus assimilis Chaudoir. Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

Calathus melanocephalus (L.). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

C. micropterus (Duftschmid). Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

Pterostichus diligens (Sturm). Loch Einich, E. Inverness (NN9198), Vc96, 22/6-24/7/01, SB.

Olisthopus rotundatus (Paykull). Loch Einich, E. Inverness (NN9198, NN9199), Vc96, 22/6-24/7/01, SB.

DYTISCIDAE

Coelambus confluens (Fabr.). Murton Farm, Forfar, Angus (NO4951), Vc90, 16/5/01, GNF.

Hydroporus longicornis Sharp. Old fishpond, West Perthshire (NN357283), Vc87, 25/9/01; nr Aricastlich, Glen Orchy (NN242314), Vc98, 9/10/01, GNF.

H. rufifrons (Müller). Strath Orchy, Argyll (NN1427), Vc98, 23/6/01, GNF.

Oreodytes alpinus (Paykull). Loch Brora (NC852084), Vc107, 14/7/01, GNF. Recently added to British list (see Hodge & Jones, 1995).

Agabus biguttatus (Olivier). Doonbank Cottage stream, Ayrshire (NS3218), Vc75, 30/9/01, GNF.

A. chalconatus (Panzer). River Brora, Balnaco (NC794106), Vc107, 15/7/01, GNF.

HYDROPHILIDAE

Hydrochus brevis (Herbst). Pool beside Loch Vaa, Moray (NH911177), Vc95, 14/7/01, GNF.

Helophorus granularis (L.). Loch Brora (NC852084), Vc107, 14/7/01, GNF.

HYDRAENIDAE

Hydraena rufipes Curtis. Loch Yarrows, Caithness (ND306447), Vc109, 14/7/01, GNF.

STAPHYLINIDAE

Carpelimus bilineatus Stephens. Stenness, Orkney, 1 male in remains of long-disused midden (HY299113), Vc111, 30/5/01, MS.

C. pusillus (Gravenhorst). Stenness, Orkney, plentiful in remains of long-disused midden (HY299113), Vc111, 30/5/01, DL.

Philonthus politus (L.). Stenness, Orkney, 1 male in remains of long-disused midden (HY299113), Vc111, 30/5/01, DL.

P. rectangulatus Sharp. Stenness, Orkney, 1 male in hay in disused byre (HY299113), Vc111, 30/5/01, MS (det. J.A. Owen).

Falagria caesa Erichson. Stenness, Orkney, several in disused midden (HY299113), Vc111, 30/5/01, MS.

Atheta (Datomicra) celata (Erichson). Stenness, Orkney, abundant in heap of mown grass (HY299112), Vc111, 30/5/01, MS.

SCIRTIDAE

Cyphon pubescens (Fabr.). Loch Baile a' Ghobhainn, Lismore (NM861426), Vc98, 23/6/01, GNF.

C. laevipennis Tournier. Wester Duncanstone, Aberdeenshire, pondside vegetation (NJ5626) Vc93, 1/7/01, AWE. *C. laevipennis* is the now regarded as the correct name for *phragmiteticola* Nyholm (*see* Klausnitzer, 1998).

C. kongsbergensis Munster. Insh Marshes, Inverness-shire, vegetation in marsh (NH7800), Vc96, 2/7/01, AWE; Rhilochan, Knockarth (NC742071), Vc107, 15/7/01, GNF. This species added to British list (Hodge & Jones, 1995) since Kloet & Hincks (1977).

ELMIDAE

Riolus cupreus (Müller). Kilcheran Loch, Lismore (NM829393), Vc98, 23/6/01, GNF.

PTINIDAE

Mezium affine Boieldieu. Maryhill, Glasgow, in old upholstered furniture (NS5669), Vc77, 12/01, EGH.

Trigonogenius globulus Solier. Maryhill, Glasgow, in old upholstered furniture (NS5669), Vc77, 3/01, EGH.

CRYPTOPHAGIDAE

Atomaria lewisi Reitter. Stenness, Orkney, fairly plentiful in heap of mown grass (HY299112), Vc111, 30/5/01, MS.

A. apicalis Erichson. Stenness, Orkney, very plentiful in heap of mown grass (HY299112), Vc111, 30/5/01, MS.

COCCINELLIDAE

Coccinella undecimpunctata L. 11-spot ladybird. Pinbain Burn, nr Girvan, about 20 individuals in company of 2-spot ladybirds (NX138915), Vc75, 23/6/01, K&SF.

LATHRIDIIDAE

Enicmus histrio Joy & Tomlin. Stenness, Orkney, 2 males and 1 female in heap of mown grass (HY299112), Vc111, 30/5/01, MS.

RHIPIPHORIDAE

Metoecus paradoxus (L.). Battleby, Redgorton, Perth, 1 male (NO0530), Vc88, 11/9/01, IMcG.

DERODONTIDAE

Laricobius erichsoni Rosenhauer. Castle Fraser, Aberdeenshire, under storey in mixed woodland (NJ724134), Vc92, 6/9/01, AWE. Added to British list by Hammond & Barham (1982). In addition to those in Peacock (1993) there appear to be two earlier unpublished records represented by specimens in the Hunterian Museum (Zoology) insect collections, *viz*., on spruce, Penicuik House, Midlothian (NT2458), Vc83, 29/9/86, R.A. Crowson; Stanley, Perthshire, River Tay flood drift (NO1133), Vc88, 10/2/89. K.H. Lockey.

CHRYSOMELIDAE

Donacia clavipes (Fabr.). Kilcheran Loch, Lismore (NM829393), Vc98, 23/6/01, GNF.

CURCULIONIDAE

Otiorhynchus armadillo (Rossi). Dalry, Edinburgh, in open scrubby area (NT237726), Vc83, 22/7/2000, BS. Although this record is for the previous year it warrants mention as being the 3rd British record of an introduced but not established species (det. Max Barclay, Natural History Museum, London).

Polydrusus splendidus (Herbst). Dalry, Edinburgh, 2 females on birch foliage (NT237726), Vc83, 22-24/7/2000, BS (det. confirmed by J.A. Owen). New to Scotland.

Eubrychius velutus (Beck). Insh Marshes, Inverness-shire, in lochan (NH7800), Vc96, 22/7/01, AWE.

DIPTERA

DOLICHOPODIDAE

Medetera inspissata Collin. Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NH779003), Vc96, 24/06/01, TB. Red Data Book status ' 3'.

HYBOTIDAE

Tachypeza nubila (Meigen). Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NH779003), Vc96, 15/06/01, TB.

SYRPHIDAE

Xanthandrus comtus (Harris). Craigieburn, nr Moffat, Dumfries-shire, spruce plantation on hogweed flowerhead (NT125063), Vc72, 14/9/01, KW. A very rare Scottish species with previous records detailed by Watt (2002); British RDB status 'Notable'.

Hammerschmidtia ferruginea (Fallén). Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NH7700), Vc96, 3/07/01, TB; Dulicht, nr Granton-on-Spey, larvae under bark of fallen aspen (NJ0327), 30/4/01, EGH. Red Data Book status ' 1'.

Xylota tarda Meigen. Insh Marshes, Kingussie, Inverness-shire on dead aspen (NN776994), Vc96, 4/07/01, TB. Red Data Book status 'Notable'.

Ferdinandea cuprea (Scopoli). Inverfarigaig, Inverness-shire on *Achillea millefolium* (NH522238), Vc96, 10/08/01, TB.

Sericomyia silentis (Harris). Inverfarigaig, Inverness-shire On *Succisa pratensis* (NH522237), Vc96, 10/08/01, TB.

Cheilosia illustrata (Harris). Inverfarigaig, Inverness-shire, on *Achillea millefolium* (NH522238), Vc96, 10/08/01, TB.

Leucozona laternaria (Müller). Inverfarigaig, Inverness-shire, on *Achillea millefolium* (NH522238), Vc96, 10/08/01, TB.

Volucella pellucens (L.). Glenborrodale, Ardnamurchan, swept from roadside vegetation at entrance to RSPB car park (NM6061), Vc97, 27/07/01, TB.

ULIDIIDAE (=Otitidae s.l.)

Homalocephala biumbratum (Wahlberg). Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NN776994), Vc96, 24/06/01, TB. Red Data Book status ' 1'.

LONCHAEIDAE

Lonchaea hackmani Kovalev. Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NH779033), Vc96, 20/06/01, TB. Added to British list by McGowan & Rotheray (2000).

L. fugax Becker. Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NH779003), Vc96, 27/06/01, TB.

CLUSIDAE

Clusiodes apicalis (Zetterstedt). Insh Marshes, Kingussie, Inverness-shire, on dead aspen (NN776994), Vc96, 28/06/01, TB. Red Data Book status 'Notable'.

CALLIPHORIDAE

Cynomya mortuorum (L.). Invertromie Meadow, Kingussie, Inverness-shire, swept from vegetation in herb-rich meadow (NN776996), Vc96, 22/07/01, TB.

CONTRIBUTORS

Tracey Begg (TB); Shona Blake (SB); Jim Black (JPB); Keith Bland (KPB); David Bowker (DB); R. Campbell (per L. Farrell) (RC); John Clayton (JC); Ruth Dobson (RD); Arthur Ewing (AWE); Stuart Glen (SWG); G.N. Foster (GNF); Keith & Susan Futter (K&SF); Allister Hamilton (AH); Geoff Hancock (EGH); David Hayes (DH); Lawrie King (LK); Derek Lott (DL); Iain McGowan (IMcG); David Mellor (DM); John Mitchell (JM); Bob Saville (BS); Magnus Sinclair (MS); Ruth Thompson (RT); Gordon Watson (GW); Kenneth Watt (KW); David & Anne Welham (D&AW); AE Whittington (AEW); Jim Wilson (JW); Elizabeth Young (EY); Bernie Zonfrillo (BZ).

REFERENCES

Bradley, J.D. (1998). *Checklist of Lepidoptera recorded from the British Isles*. Fordingbridge, Hants.

Bradley, J.D. & Fletcher, D.S. (1979). *A Recorder's Log Book or Label List of British Butterflies and Moths*. Curwen Books, London.

Chandler, P. J. (1998). *Checklists of British Insects (New Series) Diptera*, **12**. Royal Entomological Society of London, London.

Christie, I.C. (1984). Lepidoptera in Strathclyde, 1983. *Glasgow Naturalist* **20**, 435-438.

Hammond, P.M. & Barham, C.S. (1982). *Laricobius erichsoni* Rosenhauer (Coleoptera: Derodontidae), a species new to Britain. *Entomologist's Gazette* **33**, 35-40.

Hodge, P.J. & Jones, R.A. (1995). *New British beetles species not in Joy's practical handbook*. British Entomological & Natural History Society, Reading.

Klausnitzer, B. (1998). Über die *Cyphon*-Arten Henri Tourniers. *Beiträge zur Entomologie* **48**, 411-415.

Kloet, G.S. & Hincks, W.D. (1964). *A Checklist of British Insects (2nd ed.), part 1, Small Orders and Hemiptera*. Royal Entomological Society of London, London.

Kloet, G.S. & Hincks, W.D. (1977). *A Checklist of British Insects (2nd ed.), part 3, Coleoptera & Strepsiptera*. Royal Entomological Society of London, London.

Kloet, G.S. & Hincks, W.D. (1978). *A Checklist of British Insects (2nd ed.), part 4, Hymenoptera*. Royal Entomological Society of London, London.

McGowan, I & Rotheray, G.E. (2000). New species, additions and possible deletions to British *Lonchaea* Fallén (Diptera, Lonchaeidae). *Dipterists Digest* **7**, 37-49.

Peacock, E.R. (1993). Adults and larvae of hide, larder and carpet beetles and their relatives (Coleoptera: Dermestidae and of derodontid beetles (Coleoptera: Derodontidae). *Handbooks for the Identification of British Insects* **5**(**3**), 1-144.

Watt, K. (2002). Scotland's hoverfly recording sheme: *Xanthandrus comtus* back from the edge of extinction. *Hoverfly Newsletter* **33**, 11.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 35-38.

THE NATURAL HISTORY OF THE GLASGOW BOTANIC GARDENS PLANTS GROWING IN A WILD STATE 1998-2001

P. Macpherson
15 Lubnaig Road, Glasgow G43 2RY

INTRODUCTION

During the years 1994-1997 members of the Glasgow Natural History Society visited the Glasgow Botanic Gardens on a regular basis to record the wildlife. The results were published in a series of articles in the *Glasgow Naturalist* of 1998, including one on the 279 plants considered to be growing "in a wild state" (Macpherson 1998). I have continued to record in the Gardens on at least two occasions per year and, in addition, had a number of plants drawn to my attention by Keith Watson and Jean Millar. For recording purposes the Gardens are in Lanarkshire (VC 77).

A further 85 flowering plants have been recorded. Of these 30 (35.3%) are regarded as being native and 55 (64.7%) aliens. In the latter category, 16 are presumed to have arrived on site by natural dispersal, 11 to be accidental introductions and 28 to have been planted originally in the Gardens but subsequently spread to another area (Fig. 1). As before, in a number of cases it was difficult to be sure of the status but all have been allocated to that considered to be the most likely, rather than having a doubtful category. This difficulty arose particularly in the Natural Dispersal and Accidental Introduction categories. The lists of plants in the various categories are given as an appendix.

The 55 aliens have been subdivided further according to their persistence state: 18 are established, 7 are surviving and 30 of casual occurrence. The definitions used are those recommended by the Botanical Society of the British Isles (Macpherson, *et al.* 1996).

SITE SURVEYS

The previous report highlighted the presence of cotoneasters at the long abandoned railway station near the main entrance to the Gardens. In recent years the area has been surrounded by an impenetrable fence, but looking through, I have not noticed any new species. However, *Cotoneaster lomahuensis* can be added to the list. It was first seen in 1995 but only identified recently (as sp. nov.). *C. divaricatus* has now been recorded as well established along a river bank fence.

Fallow beds have again been the source of interesting records. Of particular note are Common Amaranth (*Amaranthus retroflexus*), Rough Bent (*Agrostis scabra*), Black-bindweed (*Fallopia convolvulus*), a Bird's-eye (*Gilia clivorum*), Scarlet Pimpernel (*Anagallis arvensis*)- both in its scarlet and blue forms, Bristly-fruited Mallow (*Modiola caroliniana*) and Lesser Swine-cress (*Coronopus didymus*) all considered to be native or accidental and Beet (*Beta vulgaris* sl), Red-maids (*Calandrinia ciliata*), Skunkweed (*Navarretia squarrosa*), and Vervain (*Verbena officinalis*) all recorded as having been grown elsewhere in the Gardens.

Path sides in this area have been sites for Hoary Cinquefoil (*Potentilla argentea*) and Trailing Tormentil (*Potentilla anglica*) presumed to be native or of accidental occurrence and Chamomile (*Chamaemelum nobile*) which has been grown in the Gardens. At a path side in a more remote area there is a colony of Great Tussock-sedge (*Carex paniculata*) for which there is no planted record and Flax (*Linum usitatissimum*) has been seen, presumably the result of birdseed scattered by visitors.

On the river bank there is a tiny colony of Water-pepper (*Persicaria hydropiper*) and a larger one of Bithynian Squill (*Scilla bithynica*) which presumably migrated from elsewhere downstream to the site. Strictly speaking, it is not actually in the Gardens, but is above the weir which we have taken before to be the southern extremity. Elsewhere there are established colonies of *Narcissus* taxa.

On a rough grassy bank there is a colony of Cyclamen (*Cyclamen* spp.) and a single plant of Stinking Hellebore (*Helleborus foetidus*). I have ascertained that *C. hederifolium* and *C. coum* were planted here in 1996, but not the hellebore.

In the neighbourhood of the dump area at the north end of the Garden there have again been some interesting casuals, including Green Alkanet (*Pentaglottis sempervirens*) and Balm-leaved Figwort (*Scrophularia scorodonia*).

FAMILY RECORDS

In the previous report it was noted that one alien and 16 native grasses had been recorded in the Gardens. An additional four have been seen: the natives Black Bent (*Agrostis gigantea*), Hairy-brome (*Bromus ramosus*) and Tall Fescue (*Festuca arundinaceae*), and Rough Bent (*Agrostis scabra*) an accidental introduction from North America to Glasgow, first recorded in 1979 (Macpherson & Stirling 1980).

Three extra ferns have been noted: Maidenhair Fern (*Adiantum capillus-veneris*) and Brittle Bladder - fern (*Cystopteris fragilis*) on walls, and Krauss's Clubmoss (*Selaginella kraussiana*) which had "escaped" from a glasshouse.

There are three new daffodil (*Narcissus*) species or cultivars.

There have been no additions to the wood-rush (*Luzula*) or rush (*Juncus*) lists, and just one new sedge-Great Tussock-sedge (*Carex paniculata*).

DISCUSSION

In the report for the 1994-1997 period, 279 plants were recorded in a 'wild state' in the Glasgow Botanic Gardens. Of these 58.4% were regarded as native and 41.6% alien. In the recent survey, a

Status of Plants
1998-2001
N =85

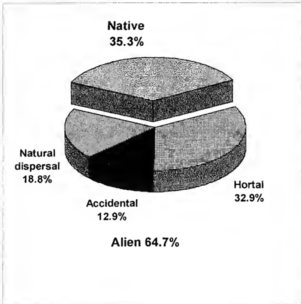


Figure 1. The native and alien status of the plants recorded in 'a wild state' in the Glasgow Botanic Gardens 1998-2001.

Status of Plants
1994-2001
N =364

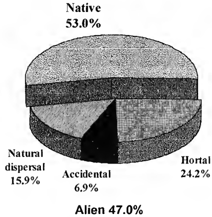


Figure 2. The native and alien status of the plants recorded in 'a wild state' in the Glasgow Botanic Gardens 1994-2001.

further 85 taxa were noted, but, as would be expected during continuous recording in such an area, the proportion of native to alien plants had reduced, there being 35.3% native and 64.7% alien. In both survey periods, in the alien categories, approximately numbers occured in the combined groups arriving either by natural dispersal or accidental introduction and those presumed to have spread from material planted elsewhere in the Gardens. However, whereas previously 70% of aliens were either established or surviving, this has been reduced to 45.5%. Again, in such an area, this can be attributed to the relatively high turnover of hortal casuals. As on the previous occasion, a number of national rarities have been recorded.

The combined totals and plant status for the entire 1994-2001 period are given in Figure 2.

Native Plants on Site

Adiantum capillus-veneris Maidenhair Fern
Agrostis gigantea Black Bent
Angelica sylvestris Wild Angelica
Bromus ramosus Hairy-brome
Centaurea nigra Common Knapweed
Chrysanthemum segetum Corn Marigold
Cystopteris fragilis Brittle Bladder-fern
Cytisus scoparius Broom
Epilobium hirsutum Great Willowherb
Euphorbia helioscopia Sun Spurge
Euphorbia peplus Petty Spurge
Festuca arundinaceae Tall Fescue
Galeopsis bifida Lesser Hemp-nettle
Hypericum x desetangsii Des Etangs' St John's-wort
Lamium purpureum Red Dead-nettle
Papaver dubium Long-headed Poppy
Persicaria hydropiper Water-pepper
Polygonum arenastrum Equal-leaved Knotgrass
Potentilla anglica Trailing Tormentil
Potentilla sterilis Barren Strawberry
Ranunculus ficaria ssp. *bulbilifer*
Lesser Celandine (bulbous)
Rorippa sylvestris Creeping Yellow-cress
Solanum dulcamara Bittersweet
Stachys x ambigua Hybrid Woundwort
Taraxacum hamatum a Dandelion
Taraxacum laticordatum a Dandelion
Valerianella locusta Common Cornsalad
Veronica beccabunga Brooklime
Vicia sepium Bush Vetch
Viola tricolor Wild Pansy

Natural Dispersal to Site

Agrostis scabra Rough Bent
Calystegia silvatica Large Bindweed
Carex paniculata Great Tussock-sedge
Cotoneaster divaricatus a Cotoneaster
Cotoneaster lomahuensis a Cotoneaster
Crocosmia paniculata Aunt Eliza
Helleborus foetidus Stinking Hellebore
Lamiastrum galeobdon ssp. *montanum* 'Variegatum'
Yellow Archangel cultiver
Lotus corniculatus var. *sativa*
Common Bird's-foot-trefoil variant
Mentha x *villosa* Apple mint
Picea abies Norway Spruce
Raphanus raphanistrum Wild Radish
Reseda luteola Weld
Senecio squalidus Oxford Ragwort
Scilla bithynica Bithynian Squill
Trifolium hybridum Alsike Clover

Accidental Introduction to Site

Anagallis arvensis Scarlet Pimpernel
Anagallis arvensis Scarlet Pimpernel (blue form)
Amaranthus retroflexus Common Amaranth
Coronopus didymus Lesser Swine-cress
Fallopia convolvulus Black -bindweed
Gilia clivorum a Bird's-eye
Linum usitatissimum Flax
Macleaya x *kewensis* Hybrid Plume-poppy
Modiola caroliniana Bristly-fruited Mallow
Potentilla argentea Hoary Cinquefoil
Veronica persica Common Field-speedwell

Originally Planted in the Gardens but spread to Site

Aucuba japonica Spotted-laurel
Beta vulgaris sl Beet
Calandrinia ciliata Red-maids
Chamaemelum nobile Chamomile
Chenopodium ficifolium Fig-leaved Goosefoot
Eruca vesicaria ssp. sativa Garden Rocket
Forsythia suspensa Golden-ball
Fuchsia magellanica Fuchsia
Heuchera cylindrica a Coralbell
Hypericum androsaemum Tutsan
Lamiastrum galeobdolon ssp. *argentatum*
Yellow Archangel subspecies
Lonicera nitida Wilson's Honeysuckle
Mahonia aquifolium Oregon –grape
Navarretia squarrosa Skunkweed
Narcissus Div 1W-W Trumpet Daffodil
Narcissus Div 3Y-YO Short-cupped Daffodil
Narcissus tazetta Bunch-flowered Daffodil
Pastinaca sativa Wild Parsnip
Pentaglottis sempervirens Green Alkanet
Primula x *polyantha* Polyanthus
Raphanus sativus Garden Radish
Ribes alpinum Mountain Currant
Scrophularia scorodonia Balm-leaved Figwort
Selaginella kraussiana Krauss's Clubmoss
Silybum marianum Milk Thistle
Symphytum tuberosum Tuberous Comfrey
Tilia x *europaea* –suckering Lime
Verbena officinalis Vervain

ACKNOWLEDGEMENTS

I am grateful to the following for help with identification: EJ Clement, AA Dudman, J Fryer, DR McKean, AJ Richards, AMcG Stirling & K Watson. Information regarding what had been planted in the Gardens was kindly provided by E Donaldson, J Logan & P Matthews.

REFERENCES

Macpherson, P (1998). The Natural History of the Glasgow Botanic Gardens. Plants Growing in a Wild State. *Glasgow Naturalist* **23**,44-49.

Macpherson, P, Dickson, JH, Ellis, RG, Kent, D & Stace, CA (1996). Plant Status Nomenclature. *BSBI News* **72**, 13-16.

Macpherson, P & Stirling, AMcG (1980). Clyde Dock Aliens. *Glasgow Naturalist* 20, 75-76.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 39-41.

COTONEASTERS 1982- 2001 IN LANARKSHIRE

P. Macpherson[1] & E.L.S. Lindsay[2]
15 Lubnaig Road, Glasgow G43 2RY [1]
18 Monreith Road, Glasgow G43 2NY [2]

INTRODUCTION

In a series of artieles we have reported on the 26 taxa of cotoneasters known to us to have been recorded in the wild in Lanarkshire (VC 77) (Macpherson & Lindsay 1992, 1993 & 1996). For each taxon we provided a drawing made from live local material. With permission these were reproduced in *The Changing Flora of Glasgow* (Dickson *et al* 2000).

Since the last report, a further seven species have been identified. In addition to constituting a new vice-county record, each was usually the first record for a much wider area. These occurrences are described in detail and, as before, a drawing provided of a typical leaf in each case.

We report also on the gains and loses of the plants commented on in the previous reports.

ADDITIONAL SPECIES

***Cotoneaster ascendens* (Fig. 1. a)**

Despite its name, the single plant of this species, recorded in 1998, hangs from the stonework of a bridge over the River Nethan at Lesmahagow.

***C. ignescens* (Fig. 1. b)**

A number of strong plants are present on an abandoned railway viaduct at Dalmarnock, Glasgow. These were first seen in 2001 and constitute the first record for the plant in the British Isles.

***C. lomahuensis* sp. nov. (Fig. 1. c)**

A single plant is present in the long abandoned railway station at the south east corner of the Glasgow Botanic Gardens. It was first seen in 1995, but not reported by us before as at that time it had not been published, being a species nova.

***C. mairei* (Fig. 1. d)**

The first sighting was that of a single plant at the side of a minor road at Chapelhall in 2000 and a second on the abandoned railway viaduct at Dalmarnock in 2001.

***C. marginatus* (Fig 1. e)**

A number of plants grow in relation to a pathside railing at Firhill, Glasgow, where the plant is well established. They were first seen in 1998.

***C. microphyllus* (Fig. 1. f)**

This name was initially used for plants now regarded as being C. integrifolius. True *C. microphyllus* was confirmed in 2001 from the Dalmarnock viaduct. This constitutes a second British record.

***C. nitens* (Fig. 1. g)**

A single plant, first seen in 1998, grows in roadside scrub at Bothwell.

In addition to the above, we report on a colony of strong plants growing on the bank of the River Kelvin adjacent to the railings and bridge on Kelvin Way. It was thought originally that at least one might have been *C. henryanus* and further material was requested. In 2000 flowering and then fruiting specimens were taken from each plant. The verdict has been that all have a basis of *C. frigidus*, either alone, or in combination with *C. salicifolius* (*C.* x *watereri*) , and that in one case *C. henryanus* is involved.

UPDATES OF THE TAXA PREVIOUSLY REPORTED

The totals given relate to 1Km square records over the entire survey period. In a number of cases, there is more than one site within the square. When there are from one to five new records the site locations are given. We consider it appropriate to point out that there are four separate abandoned industrial sites at Shettleston. In a few instances we refer to the Glasgow Rectangle. This is more-or-less Greater Glasgow, and the study area for *The Changing Flora of Glasgow*.

C. adpressus

Total 3. In 1986 a plant presumed to be this species was seen on a bing complex, but the site was cleared for development before further material could be obtained for positive identification. There are now two verified records. In 1999 seedlings were seen in an abandoned industrial site at Shettleston, Glasgow, and on waste ground in Drumpellier Country Park

C. astrophoros

Total 1. This has not been refound, despite a search in 2001.

C. atropurpureus

Total 6. Only one of the three plants reported in 1992 is extant, but during 1999 three further reeords were made: sloping woodland at Glenboig, spontaneous appearance in a garden at Sandford and in abandoned industrial ground at Shettleston.

C. boisianus

Total 1. No change.

C. bullatus

Total 29. In our last report we noted that there had been 18 records with only two losses. Since then there have been 11 additional sightings. As the plant is so widespread, no attempt has been made to check that the plant is still present at the other old sites. Six of the total have been recorded outwith the Glasgow Rectangle.

C. cashmiriensis

Total 1. The extermination of the the single plant was previously reported.

C. conspicuus

Total 8. At the time of the last report, the plant was still present in three of its four sites. At one of these, Kingston, the plant has been eradicated, but we have made four additional records. On grassy waste ground at Cessnock, Glasgow in 1996 (now gone),

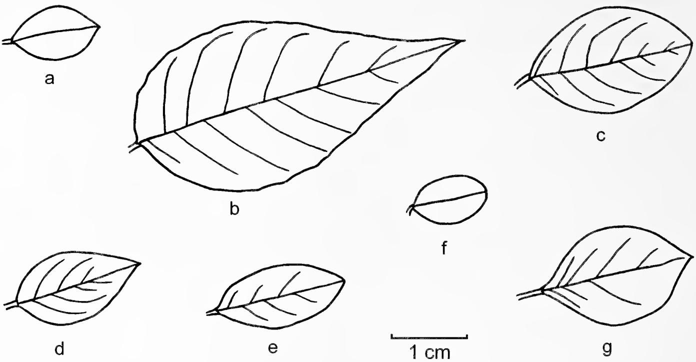


Figure 1. Leaves of Cotoneaster species. (a) *C. ascendens*; (b) *C. ignescens*; (c) *C. lomahuensis*; (d) *C. mairei*; (e) *C. marginatus*; (f) *C. microphyllus*; (g) *C. nitens*.

barish waste ground at Drumpellier in 1999, abandoned industrial estate at Shettleston in 2000 and scrubby grassland at Forgewood, north of Motherwell in 2001.

C. dammeri

Total 4. Of our three previous records, only that on waste ground at Dalmarnock is extant and we add the occurance on a soil heap at the Bothwell Riding School in 2000.

C. dielsianus

Total 9. Added to our three previous records are six in such habitats as adjacent to a hedge and in a wood.

C. divaricatus

Total 5. In 2000 plants were noted growing on the walls of a ruined castle at Highouse, north of Biggar, abuntly along a railing by the River Kelvin and in an abandoned industrial site at Shettleston. These, plus the two previous sites where the plants survive, take the total to five.

C. franchetii

Total 12. As far as we know, the plant is still present in seven of the eight sites previously reported. Of the four new records, three were seen in 1997: a bing complex at Easter Hessockrigg, a wood at Auchenshuggle, Glasgow and a path side at Provan Hall. The fourth was noted on the viaduct at Dalmarnock in 2001

C. frigidus

Total 2. No change, the plants survive at both sites.

C. helmqvistii

Total 4. The additional to the previous records is the occurrence noted in 1988 at a pathside at Stepps.

C. horizontalis

Total 26. Since the last report we have made 11 new records. This is the second most widespread cotoneaster in Lanarkshire, with 10 sites outwith the Rectangle.

C. hylmoei

Total 2. The strong plant on a rough grassy slope at Laigh Mains, East Kilbride survives, but that at Cessnock has been exterminated by industrial development.

C. integrifolius

Total 8. Our only previous record was that of a seedling between granite setts at the Custom House Quay. The new occurrences include a plant adjacent to a dockland fence and another with numerous seedlings on semi-bare ground in an old industrial site.

C. lacteus

Total 1. No change, a plant is still present at the site of the old Botanic Gardens Station.

C. rehderi

Total 2. The plant previously seen at Eastfield, Rutherglen can no longer be found, although there is no evidence of disturbance to the area. In 1999 a plant was noted adjacent to an abandoned building at the back of the King George V Dock. This is the only record for which we have doubt regarding status—it could have been planted at some time in the past.

C. salicifolius

Total 18. We know that one of the 12 previously reported has been lost due to development, but have not made an effort to check on the others. The additional six are in habitats such as abandoned industrial sites and a track side.

C. sherriffii

Total 1. We have been unable to refind this plant, but as it grew in thick undergrowth it could well have been missed.

C. simonsii

Total 54. With 34 records, this was the most common cotoneaster taxon in our previous report, and the addition of a further 20 keep it in that position. It has the most widespread distribution in the vice-county with 16 sites outwith the Rectangle.

C. sternianus

Total 2. In our last report we noted that the plants at Cessnock were thriving and increasing in number, but during 2001 they were obliterated by site development. Those in a shrubby wood near the South Rotunda are still present.

C.* x *suecicus

Total 8. Of the six previous records, only those at the edge of a wood in the grounds of the Southern General Hospital and on the abandoned viaduct at Dalmarnock persist. Of the two new records one is from an abandoned industrial site at Shettleston. With regard to the other, this is the only cotoneaster which we have found in the extreme south of Lanarkshire. A plant was seen in 2000 growing up against a grating which had been placed as a filter across a small burn. The initial thought was that the plant had been washed down and caught by the grating where it took root, but perhaps it is more likely to have been sown by a bird perched on the metal work. In addition to the above, in 1995 the cv. Skegholm was noted adjacent to a roadside wall at Plains, Airdrie.

C. villosulus

Total 1. No change.

C.* x *watererii

Total 16. Only one of the eight previous records has been lost. Habitats for the additional eight include the edge of a small wood and waste ground. All but one are within the Rectangle.

DISCUSSION

The vast majority of plants occur alongside railings, parapets or buildings or under trees, indicating spread by bird dropping. It was noted before that this was particularly evident on an abandoned railway viaduct at Dalmarnock, where plants were growing at the sides of the parapets. At a re-survey in 2001, an additional four species were seen in this location. Over a 20 year period we have recorded 33 taxa of cotoneaster in VC 77, a higher total than that given in any of the vice-county floras that we have consulted. This could be the result of a greater number of taxa being grown locally in gardens and/or as amenity planting, or because we have made a practice of sending most of the plants seen for specialist identification.

ACKNOWLEDGEMENT

We are exceedingly grateful to Jeanette Fryer for identifying the large batches of specimens sent over the years.

REFERENCES

Dickson, JH, Macpherson, P & Watson, K (2000). *The Changing Flora of Glasgow*. Edinburgh University Press.

Macpherson, P & Lindsay,ELS (1992). Cotoneasters in the Glasgow Section of VC 77. *Glasgow Naturalist* 22, 111-114.

Macpherson, P & Lindsay, ELS (1993). Cotoneaster Update. *Glasgow Naturalist* 22, 239-242.

Macpherson, P & Lindsay, ELS (1996). Cotoneasters Continued. *Glasgow Naturalist* 23,11-13.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 43-46.

BARBEL *BARBUS BARBUS* IN THE RIVER CLYDE: A NEW FISH SPECIES ESTABLISHED IN SCOTLAND

Peter S. Maitland[1] & William W. Miller[2]

Fish Conservation Centre, Gladshot, Haddington, EH41 4NR [1]

7 Brooklands Avenue, Glasgow, G71 7AT [2]

ABSTRACT

The Barbel is a new fish species to the Scottish fauna. It is believed that, following earlier attempts at introduction, adult fish were introduced to the River Clyde from England during the early 1990s and are now establishing there, with juvenile fish being caught during 2000. Although adding to the diversity of coarse fish available to Clyde anglers, the presence of the Barbel is likely to be disadvantageous to native fish there, especially Atlantic Salmon which is still re-establishing after a century's absence.

INTRODUCTION

Scotland has seen numerous introductions of alien species over the last 150 years and more than one third of the Scottish ichthyofauna is now made up of species introduced from abroad (Adams & Maitland, 2002). The most notable introduction in recent years was the Ruffe *Gymnocephalus cernuus*, which was introduced to Loch Lomond about 1980 (Maitland *et al.,* 1983; Adams & Maitland, 1998) and is now well established there and in other waters in Scotland (e.g. Loch Ken and the Forth and Clyde Canal). The latest in this series of alien fish is the Barbel *Barbus barbus*, which appears now to have become established in the River Clyde.

One of the earliest fish introductions to the River Clyde was the Grayling *Thymallus thymallus*, which was first released there in December, 1855, when three dozen fish were placed in the river near Abington. Some 150 years later, the Grayling is well established and distributed throughout most of the river (and much of Scotland from the River Tay southwards) and a species favoured by many anglers (Miller, 1987). There is every reason to expect the Barbel to do equally well in time, although its northern credentials are not as good as those of the Grayling and it may not be so favoured during cooler summers.

Judging by its favoured habitats elsewhere, the River Clyde should prove suitable for the Barbel. Like the Rivers Avon and Severn, in which it occurs in England, the Clyde is a large river, with extensive stretches of deep fast flowing water for adults, many suitable areas of gravelly shallows for spawning, and plenty of sheltered slow-flowing backwaters and still pools which are favoured by the young fish. Much of the main River Clyde and many of its main tributaries should prove suitable for this species and, as in other rivers further south into which it has been successfully introduced, the Barbel population is likely soon to expand and occupy these favoured habitats.

ORIGIN

Full details of Barbel captured so far in the River Clyde are not available, for there is no systematic programme of recording fish catches there. Moreover, some anglers are coy about discussing the new arrival. Thus, as with so many other introductions of fish to Scotland, the details of the original introduction of this species are somewhat hazy. However, from hearsay information, it seems likely that the first Barbel were probably brought up from the River Swale or the River Ure by steel workers at Motherwell who released them in the River Clyde above Motherwell. Subsequently, local reports indicate that several batches, totalling about 50 adult Barbel altogether were transported from England and placed in the River Clyde by coarse anglers during the 1990s. The origin of this stock is believed to be the River Severn.

Unlike the introduction of Ruffe *Gymnocephalus cernuus* to Loch Lomond, which is believed to have resulted from the casual dumping of live bait at the end of a fishing trip, there is little doubt that this transfer of Barbel was a deliberate attempt by anglers to establish the species in the River Clyde. The Barbel, though of no commercial importance in Great Britain is an important species to some anglers, and is respected for its cunning and fighting qualities. Maxwell (1904) noted that 'Altogether this fish is well equipped with organs of propulsion, which enable him to make a grand fight when hooked.' Regan (1911) agreed: 'The Barbel is a strong and active, yet wary, fish, and affords fine sport to the angler.'

Barbel are now caught in the River Clyde on a regular basis, and in the year 2000 the following fish were reported to the authors: (a) A 1 lb (0.45 kg) Barbel caught and returned by someone fishing for Atlantic Salmon just downstream of Blantyre. This fish is much smaller than any of those known to have been stocked and is assumed to be one of their progeny. (b) A 'large' Barbel, caught and returned just downstream of Uddingston. (c) A 13.5 lb (6.18 kg) female Barbel, 'full of spawn', taken by a salmon angler 'a few miles upstream of Motherwell'. (d) Three large Barbel, 8.25 lb (3.71 kg), 8 lb (3.6 kg) and 5 lb (2.25 kg) caught by coarse fishermen near Motherwell (see Figure 1). These fish were of sufficient interest to feature in the 'Daily Record' (1 December, 2000) as 'Fish of the Week'.

THE BARBEL

The Barbel is found in Europe from western France across central Europe to the Black Sea (Maitland, 2000). In the British Isles, it was formerly confined to the east and south-east of England but has been

Figure 1. Three fine Barbel caught on the River Clyde near Motherwell by specialist coarse anglers

re-distributed by angling interests to several southern river systems such as the Medway, the Severn and the Bristol Avon. It is absent from Ireland and was from Scotland until the last decade of the 20th century. Adult Barbel are usually some 40-60 cm in length and 1-2 kg in weight, but the species can grow up to 100 cm in length and reach a weight of 8 kg in very favourable waters. The present British rod-caught record is for a fish of 6.237 kg caught in the River Avon in Hampshire in 1962. No Scottish record has yet been ratified.

The Barbel is characterised by the possession of two pairs of long fleshy barbels on the equally fleshy upper lip, one pair (the smaller), just in front of the snout, the other at the rear angles of the mouth. The mouth is placed ventrally back from the snout. The body, evolved for active swimming, is long and rounded with very little lateral flattening, although it is rather flat along the belly. The body is covered in medium-sized scales of which there are 55-65 along the lateral line. The Barbel is usually a brownish-green colour on the head and back which grades to a golden-brown on the sides and then to creamy white on the belly. The fins are a dull yellowish-green, sometimes with an orange tinge.

The Barbel is a bottom-living fish which occurs usually in the lowland reaches of large clean rivers, where there are stretches of clean gravel and weed beds. Spawning takes place in May and June or even into July when adult fish may move upstream and congregate in large numbers near the spawning grounds, which are over clean gravel and among open weed beds in flowing water. The eggs are yellow, 2-2.5 mm in diameter, sticky, and adhere to weed and to the gravel. Development varies with water temperature, but normally takes 10-15 days. The fry start to feed on small crustaceans and insect larvae and as they grow they move to larger invertebrates including worms, crustaceans, molluscs (both snails and mussels), and mayfly and midge larvae. Large Barbel will take small fish when they can. In good habitats the young fish may reach 10 cm after one year and 15-20 cm after two years. They mature normally at about 4-5 years of age, the males usually about a year earlier than the females and correspondingly often smaller.

DISCUSSION

Anglers who catch Barbel and are unfamiliar with the species may be in for a surprise, not to mention some potential danger! Firstly, Gordon (1920) mentions of that 'It is very quick of hearing, and often makes a noise when caught, and growls under the water.' Secondly, and more seriously, though the flesh is highly regarded in some parts of Europe, the roe (and possibly even the flesh during the spawning period) is poisonous, causing severe stomach disorders. Juliana Berners (1486) gave one of the earliest warnings about eating Barbel: 'The barbyll is a swete fysshe, but it is a quasy mete, and peryllous for mannys bodye.' Evidence is given by John Hawkins who, in notes to his edition of The Compleat Angler (Walton, 1760), recorded 'that one of his servants, who had eaten part of a Barbel, but not the roe, was seized with such a violent purging and vomiting as had like to have cost him his life.'

Regan (1911) continued with further warnings '... opinions differ as to its value as food, the flesh being white and firm, but rather coarse; the eggs are more or less poisonous, sometimes inducing violent purging and vomiting, and also weakening the heart so much that fainting may result; the poisonous secretion is sometimes absorbed by the flesh of the lower part of the fish, which may thus produce similar effects, and to be safe it is best to eat Barbel only in the late summer and autumn, and to remove the roe as soon as possible after the fish is caught.' The safest option is offered by Maxwell (1904): 'Well, and what are you to do with your Barbel when you have got him? That is just the least satisfactory part of the performance. Were Barbel a culinary prize, like Salmon, the sport would be a noble one; but most people account the fish fit for nothing better than to feed pigs withal.'

The realisation that Barbel is established in the main stem of the River Clyde follows closely on the confirmation that the North American Signal *Crayfish Pacifastacus leniusculus* is also well established in another part of the Clyde system - though this fact only recognised there relatively recently (Maitland *et al.*, 2001). This aggressive predator was first identified by the authors in the River Clyde near Elvanfoot and is now known to be common along several kilometres of the river there. Some 10,000 Signal Crayfish were taken from the river during 2000 and attempts are continuing to contain or eradicate the species. It is unlikely that these will be successful in the long-term, and more likely that it, and the Barbel, will eventually spread to many parts of the River Clyde.

Wheeler & Jordan (1990) noted that, in past translocations of Barbel in Great Britain (which have almost always used adult fish), it was normal for the acanthocephalan parasite *Pomphorhynchus laevis* to be transferred with it. Thus, though it has not yet been possible for the authors to examine any of the Scottish specimens in detail, it seems likely that this parasite has been brought into Scotland with the Barbel. Such transfers have ignored the advice that any translocations of Barbel should use parasite-free young fish from hatcheries and not the parasitised adult wild stock.

As with freshwater invertebrates (Maitland *et al.*, 2001; Maitland & Adams, 2002), this new fish species is likely to continue the scenario identified by Maitland (1987), of changing and unstable fish communities in many parts of the River Clyde. With improving water quality in the lower reaches, native species such as Atlantic Salmon *Salmo salar* and River Lamprey *Lampetra fluviatilis* are trying to make a comeback to this river after a century of absence. It is particularly unfortunate, therefore, that alien species such as Barbel and Signal Crayfish (and possibly others, as yet unidentified), likely to

act as both competitors and predators, are being introduced at this time.

Will the new population of Barbel do any significant damage to native aquatic communities in the River Clyde? This question cannot be answered with certainty. However, there is every likelihood that Barbel will compete for food and space with native fish species such as Brown Trout *Salmo trutta*. It is also likely to be a predator on the eggs and young of both Atlantic Salmon and Brown Trout, as well as other fish there. Studies on the introduced Ruffe in Loch Lomond (Adams, 1991; Adams & Maitland, 1998) have clearly shown that this one small species has caused massive ecological changes in Loch Lomond and now at least four other alien species are established there. A simpler question is easier to answer. Will the Barbel be a positive or a negative influence on the native aquatic communities of the River Clyde? Unfortunately, the answer must be negative.

Hopefully, the Barbel will be listed among those fish species to be included in forthcoming legislation on controls on the keeping or release of non-native fish in Scotland, at present being prepared by the Scottish Executive. This will parallel existing legislation in England and Wales (The Prohibition of Keeping or Release of Live Fish (Specified Species) Order 1998) and will make introductions of non-native fish to Scottish waters illegal, unless carried out under licence.

ACKNOWLEDGEMENTS

We are very grateful to Thomas McGregor for information regarding Barbel in the River Clyde and to William Weir for photographs and other details of catches. Azra and Peter Meadows made very useful comments on an earlier version of the text.

REFERENCES

Adams, C.E. (1991). Shift in pike, *Esox lucius* L., predation pressure following the introduction of ruffe, *Gymnocephalus cernuus* (L.) to Loch Lomond. *Journal of Fish Biology* 38, 663-667.

Adams, C.E. & Maitland, P.S. (1998). The Ruffe population of Loch Lomond, Scotland: Its introduction, population expansion, and interaction with native species. *International Association for Great Lakes Research* 24, 249-262.

Adams, C.E. & Maitland, P.S. (2002). Invasion and establishment of freshwater fish populations in Scotland - the experience of the past and lessons for the future. *Glasgow Naturalist* 23, 35-43.

Berners, J. (1486). *A Treatyse of Fysshynge wyth an Angle*. London.

Gordon, W.J. (1920). *Our country's fishes and how to know them.* Simpkin, Marshall, Hamilton & Kent, London.

Maitland, P.S. (1987). Fish in the Clyde and Leven systems - a changing scenario. *Proceedings of the Institute of Fisheries Management Conference* 1987, 13-20.

Maitland, P. S. (1987). Fish introductions and translocations - their impact in the British Isles. *Institute of Terrestrial Ecology Symposium* 19, 57-65.

Maitland, P.S. (2000). *Guide to freshwater fish of Britain and Europe*. Hamlyn, London.

Maitland, P.S. & Adams, C.E. (2002). Alien freshwater invertebrates in Scotland: increased biodiversity or a threat to native species? *Glasgow Naturalist* 23, 26-34.

Maitland. P.S., East, K. & Morris, K.H. (1983). Ruffe *Gymnocephalus cernua* (L.), new to Scotland, in Loch Lomond. *Scottish Naturalist.* 1983, 7-9.

Maitland, P.S., Sinclair, C. & Doughty, C.R. (2001). The status of freshwater crayfish in Scotland in the year 2000. *Glasgow Naturalist* 23, 26-32.

Maxwell, H.C. (1904). *British freshwater fishes.* Hutchinson, London.

Miller, W. (1987). Grayling with a Scottish accent. *Trout and Salmon* October 1987, 40-41.

Regan, C.T. (1911). *The freshwater fishes of the British Isles*. Methuen, London.

Walton, I. (1760). *The compleat angler*. London.

Wheeler, A. & Jordan, D.R. (1990). The status of the Barbel, *Barbus barbus* (L.) (Teleostei, Cyprinidae), in the United Kingdom. *Journal of Fish Biology* 37, 393-399.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 47-50

NEST-SITE COMPETITION WITH BLUE TITS AND GREAT TITS AS A POSSIBLE CAUSE OF DECLINES IN WILLOW TIT NUMBERS: OBSERVATIONS IN THE CLYDE AREA

James Maxwell
7 Lilac Hill, Hamilton, ML3 7HG

INTRODUCTION

Willow tits *Parus montanus* are resident and sedentary, defending their territory throughout the year, and showing a habitat preference for areas of wet woodland (Perrins, 1979). Although the numbers and range of this species across continental Europe are thought to be stable (Hagemeijer & Blair, 1997), the 'new atlas of breeding birds' showed the willow tit to have contracted in breeding range in Britain between 1970 and 1990 (Gibbons *et al.*, 1993), with a particularly large reduction in Scotland. By 1990, willow tits nested only in small pockets of the borders, Galloway, Ayrshire and the Clyde, with a single record north of the central lowlands. This contraction in Scotland follows disappearance from Inverness, Ross, Angus, Perth, Fife and the Lothians in earlier decades, which has been tentatively ascribed to factors such as severe winters during the 1940s-50s and loss of habitat (Thom, 1986). Since 1990, declines in numbers and breeding range of the willow tit have continued, and perhaps accelerated, throughout its range in Britain. Willow tit numbers on Common Bird Census plots of the British Trust for Ornithology fell by 56% during 1988-1998, and showed a 29% fall from 1998 to 1999 (Sanderson *et al.*, 2000). Lanarkshire is now the northern limit for the species in Britain, and the neighbouring small isolated populations in Ayrshire and Galloway are in serious decline to very few pairs (Murray, 2000). Winter conditions and habitat loss seem inadequate as explanations for this drastic population contraction. Willow tits are maintaining healthy populations in much colder climates, such as northern Norway, Finland and Russia (Hagemeijer & Blair, 1997), while many areas of apparently suitable breeding habitat in Scotland remain, but now lack willow tits. This study was therefore undertaken to try to find reasons for the decline of the willow tit, and in particular to test whether providing artificial nest sites within suitable breeding areas could help to maintain the remaining pairs in the now tiny and isolated population in Lanarkshire.

METHODS

Willow tit territories in Lanarkshire were located by listening for the characteristic song and contact calls of this species. Locating territories was enhanced by amplified playback of tape recordings of willow tit vocalisations, which was extremely effective in eliciting responses from willow tits within a distance of as much as 1 km. Once found, pairs of willow tits were visited throughout the year to record their presence and behaviour, especially in the early breeding season. Since there are no marsh tits *Parus palustris* in the Lanarkshire area, species recognition was simple even when based only on visual observation. Unlike blue tits *P. caeruleus* and great tits *P. major*, willow tits only nest in cavities that they excavate for themselves, normally in the rotten stump of a tree. Particular attention was given to the nest construction activities of willow tits in order to glean indications of a suitable design for a willow tit nestbox, and to monitor their breeding activity to see whether the population decline may be related to some cause of breeding failure.

The " nest box " is basically a bark-covered plastic tube with an internal nest chamber, filled to the entrance hole with fine wood shavings (design details are given in Appendix 1); it was first placed in willow tit territories and used by the birds in 1995.At present, there are 136 boxes distributed through 22 areas of Lanarkshire (Figure 1) where willow tits have been found holding territory or where they have previously bred. Of these, 7 areas currently hold breeding birds; the species has always easily located these purpose-designed boxes and excavated them readily.

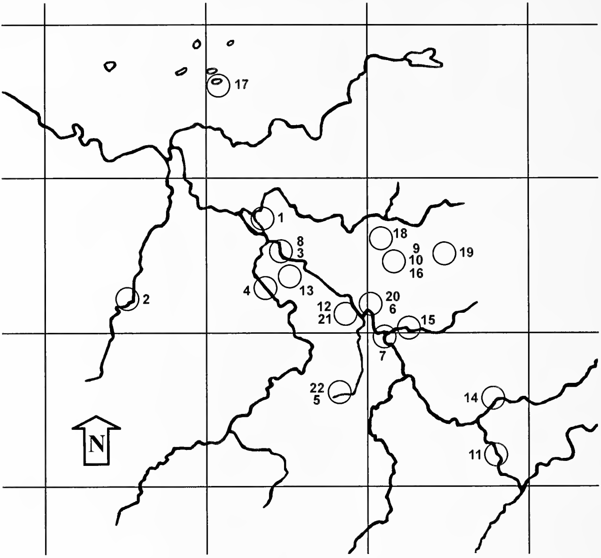
In addition to monitoring breeding success of willow tits in natural sites and in nestboxes, since 1996 the nestlings have been marked with nest-specific colour rings in order to provide information on their post-fledging survival and natal dispersal. A number of adults have also been caught on their territory during winter by mist net and marked with individual colour ring combinations, allowing their survival and pairings to be recorded.

RESULTS

Habitat, nest sites, nest construction, incubation and fledging.

Willow tit territories were located in a range of habitats, from mature woodland with minimal ground cover through regenerating woodland with moderate understorey of brambles etc., to thick birch carr with heather ground cover. Nest sites were found on flat or sloping ground, even on the sides of steep valleys. The preferred decaying timber is birch, with alder another favourite. The average hole-height above ground level in natural sites is 1.5 m, but cavities can be as high as 10.5 m from the ground. During March, willow tits were seen to make trial borings in several stumps, but by April the effort is usually concentrated on one site, with both birds actively engaged in excavation work. The entrance hole dug out is slightly oval (the long axis vertical) and about 3 cm across. Debris falls underneath the site at first, but as the excavation proceeds to form a chamber in a downward direction, the birds turn and fly out with shavings and carry them progressively further away, eventually to up to 20 m. At this stage, birds make up to 4 visits per minute, one bird waiting while the other excavates. This work is carried out in an open, busy fashion and can continue for

Figure 1. Locations of willow tit territories investigated on the R. Clyde system during the study from 1994-2001: 1=Strathclyde CPark, Motherwell; 2=Calder Glen, East Kilbride; 3=Baron's Haugh, Motherwell; 4=Chatelherault Cpark, Hamilton; 5=Candermoss, Stonehouse; 6=Garrion Gill foot, Overtown; 7=Mauldslie, Rosebank; 8=Ross Tip, Hamilton; 9=Harestonehill, Newmains; 10=Eastmuir Plan., Newmains; 11=Upper Clyde, New Lanark; 12=Millburn Glen, Larkhall; 13=Merryton, Larkhall; 14=Cleghorn Glen, Lanark; 15=Jock's Gill, Carluke; 16=Greenhead Wood, Waterloo; 17=Drumpellier Cpark, Coatbridge; 18=Coltness Woods, Coltness; 19=Auchter Water, Newmains; 20=Garrion Gill head, Overtown; 21=Upper Millburn, Ashgill; 22=Canderwood, Stonehouse.



several days. When the cavity is complete, the female then builds a minimal nest - a felt-like pad of fine hairs, grasses and fibres. She incubates, and is fed on the nest by the male, but occasionally leaves the eggs unattended, concealing them with ruffled nest material. Both parents share chick-feeding duties and when the young fledge, they are dependent for about a fortnight, then gradually disperse.

Use of nest boxes, and breeding data

The "nestbox " (Appendix 1) has proved very successful, and is regularly adopted by willow tits. In 1996, 5 young fledged from a nest box at Strathclyde Country Park and a pair held territory at Baron's Haugh. In 1997, two pairs bred in the Wishaw and Lanark areas, both in nestboxes, and produced 14 young. Five pairs were located in 1998, producing 28 young. In 1999, two pairs were successful in natural stumps, producing 14 young. In 2000 there were six pairs producing 47 young (two pairs in nestboxes, four in natural sites), and in 2001, three pairs in natural stumps had 17 young. A fourth pair at Coltness used a box to the nesting stage but then deserted (see further note). Sightings of unringed birds hinted at the existence of other breeding pairs in the area but there are probably no more than 8-20 pairs of willow tits now remaining in Lanarkshire .

Site fidelity and dispersal

A colour ringed male willow tit has bred at the same site at Eastmuir Plantation, Newmains, each year for four successive seasons, but each season

with a different female. Young birds given site-specific colour rings were found establishing a territory, on average, only about 1-2 km from their natal site. In Lanarkshire, the main stronghold of willow tit breeding is in the area centering on Newmains, Wishaw and Coltness, with other sites near Larkhall. One fledgling travelled 6 km from Coltness to a site at Baron's Haugh. From one brood of 9 chicks at Larkhall (in 2000), one moved to Baron's Haugh (5 km), one to Wishaw (4 km), one to Garrion Gill (3 km) and one moved 2 km, all in different directions. The Garrion Gill female has bred (in 2001) with a previously dispersed male bird from Larkhall (1998) – i.e. this pair shared the same parent and did the same journey, but two years apart. In spite of this kind of consistency in dispersal, many young, including 3 whole broods out of 16, have never been traced, so either dispersed to unknown locations or did not survive.
The two Willow Tits that dispersed all the way to Baron's Haugh were males and apparently did not find females in 2001 and have left that area.

Interactions with blue 0 tits

At nut feeders during winter, willow tits are subordinate to great tits and blue tits. Similarly, at nest sites, willow tits can be displaced by great tits or blue tits. Observations of willow tits in the Lanarkshire study area showed that these birds frequently lose their newly excavated nest site to a pair of blue or great tits. During five years of study till 2000, of only some 30 willow tit pair-years, I observed 18 nest take-overs by blue tits and two by great tits. Of these, 16 were take-overs of newly excavated nestboxes, and four were take-overs of newly excavated natural sites. This probably underestimates the frequency of take-over of natural sites since it was easier to make observations at nestboxes. One example of this interaction was recorded at the territory of a pair of willow tits at Strathclyde Country Park in 1995. This pair excavated five successive nestboxes, losing each in turn to pairs of blue tits. In mid-May, they at last got to the egg stage in a nest-box, only to fail, due to heavy snow. Eventually in late May, their last box was excavated, but, due possibly to energy depletion, only to a depth just under the nest-hole. In the later stages, this inevitably left the young openly vulnerable to predators and the brood was lost (Nilsson 1984). Meanwhile the Blue Tits had raised families successfully in all their acquired sites. In the 2001 breeding season alone, there were 7 Blue Tit and 6 Great Tit take-overs from the nest-boxes. In the afore-mentioned Coltness failure at the nest stage, both Blue Tit and Great Tit pairs were seen showing great interest in the nest, although they did not use the box. It may well be that even at the nest stage, aggression by the dominant tits can be sufficient to make a pair desert, as was witnessed at Jock's Gill in 1999, when the Willow Tits were witnessed being chased around the nest area before deserting.

DISCUSSION

In colder countries such as Russia and Finland, young birds usually join adults in adjoining areas and capitalize, in the winter, on food that the older birds have stored (Cramp & Perrins, 1993). In Lanarkshire, storing food seems not to be so vital, and youngsters are often found holding territories on their own in the post-natal year. Willow tits in Lanarkshire seem rarely to join winter mixed flocks of tits, but remain in their territory throughout the year. The dispersal of juveniles from their natal territory to establishing a territory of only a few hundred meters to a few kilometres away is typical of willow tits in Britain; Cramp & Perrins (1993) state that 78% of willow tit ring recoveries came from within 5 km of the ringing location. Only one recorded movement in Britain exceeded 50 km. This would suggest that the Lanarkshire population of willow tits is effectively a closed, isolated population, since the nearest (Ayrshire) population is almost extinct, and the (declining) Galloway and Borders populations are about 100 km away, so are unlikely to provide immigrants to the Lanarkshire area.
The specially designed nestboxes were readily accepted by willow tits and good numbers of young have been reared in these boxes. Wired to a tree at knee to shoulder height they look like bark-covered stumps with a tempting bit of decay, which attracts investigative pecking. They satisfy several criteria; being light to carry, cheap to make, waterproof, fairly long-lasting and unobtrusive, so that they are not noticed when in vandal-prone areas. They have also proved invaluable in monitoring the presence of Willow Tits in new areas, as they are always excavated if the species is there. Although it is unlikely that willow tits are limited by a lack of natural sites for nesting, the nestboxes are particularly easy to excavate, and so the energetic cost of cavity construction will be much reduced. This may be important given the problems willow tits face from blue tits and great tits. My observations strongly suggest that an important factor in the decline of the willow tit has been the tendency for blue tits and great tits, having witnessed all the afore-mentioned excavation activity , to take over newly excavated willow tit nest chambers, forcing the willow tits to start a new excavation elsewhere. A series of such thwarted attempts to breed may impair the body condition of adult willow tits, and it is a general feature of birds that late breeding tends to be less successful and fledglings reared late in the season tend to have low survival prospects (Perrins & Birkhead, 1983), (Bromssen and Jansson, 1980). It is likely that blue tit and great tit populations have increased over recent decades as a result of increased provision of winter food in suburban gardens. It is also possible that these species, facing gradually reducing nesting facilities due to the great development of improved housing etc. since the fifties, have expanded into typical willow tit habitat to breed; if so, their liking for new, ready-made sites may be the main cause of

the demise of willow tits. This hypothesis invites further research. At the suggestion of Chris Mead (BTO), placing willow tit nest boxes in pairs may help to mitigate this interaction; blue tits take over the first excavated nest box, but permit the willow tits to nest in the adjacent box. Preliminary evidence (in 2000) suggested that this was an effective strategy, but although many nest-box placings were converted to this system in 2001, there was still no significant improvement. Further experimenting along these lines will take place.

ACKNOWLEDGEMENTS

I am most grateful to the Hamilton branch of the RSPB and Neil Darroch for help in willow tit surveying fieldwork, Matt Mitchell for nest-box work, and Iain Livingstone for ringing the birds. I thank North Lanarkshire Council for their interest and support, the BTO, SNH and B&Q for funding this study, and Bob Furness for generous advice in the preparation of this paper.

REFERENCES

Bromssen, A. Von & Jansson, C. (1980) Ornis scandinavica 11: 173-178

Cramp, S. & Perrins, C.M. (eds.) (1993). *The Birds of the Western Palearctic* Vol. VII. Oxford University Press.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993). *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. T & AD Poyser.

Hagemeijer, W.J.M. & Blair, M.J. (1997). *The EBCC Atlas of European Breeding Birds*. T & AD Poyser.

Murray, R. (2000). 1998. *Scottish Bird Report No. 31*. Scottish Ornithologists Club

Nilsson, S. G. (1984) Ornis scandinavica 15: 167-175.

Perrins, C. M. (1979). *British Tits*. Collins.

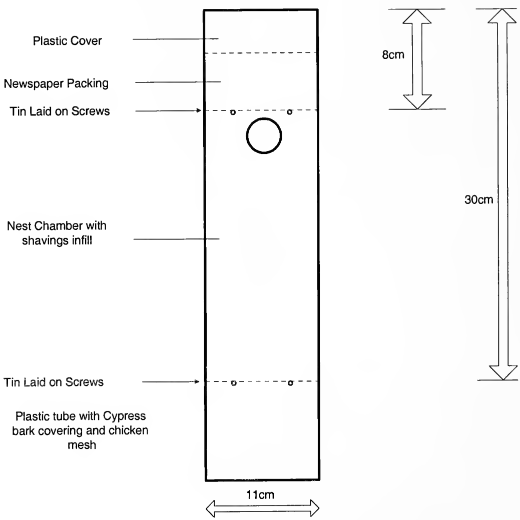
Perrins, C.M. & Birkhead, T. R. (1983). *Avian Ecology*. Blackie.

Sanderson, F., Marchant, J. & Glue, D. (2000). Changes in breeding bird populations, 1998-99. BTO *News* 228, 10-13.

Thom,V.M. (1986). *Birds in Scotland*. T&ADPoyser.

APPENDIX 1. Details of the willow tit " nest box " design used in this project.

The Willow tit nest box is constructed from a plastic tube of 11 cm diameter, covered with Cypress bark held in place by chicken mesh. Two tin lids are laid on screws to limit the size of the nest chamber to 22 cm high, with crumpled newspaper used to fill the space above the upper lid. The tube between the two lids is filled with wood shavings. An entrance hole of 3 cm diameter is cut in the tube, 10 cm from the top. The top of the tube is sealed with a plastic cover. The nest box is attached to a tree trunk at about 1-2 m off the ground. Placing nest boxes in pairs, about 3 m apart, seems to be the best way to ensure that willow tits are able to nest in one of the pair of boxes if blue tits or great tits are active in the area.



Glasgow Naturalist 2002. Volume 24. Part 1. Pages 51-58.

THE SCOTTISH LYNX: IS REINTRODUCTION A POSSIBILITY?

Katie McDonald

Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow. G12 8QQ.

INTRODUCTION

The reintroduction of a species must fulfil two criteria to be viable. First it must be feasible from the point of view of all involved – the subject (the species to be returned), the host (the ecosystems into which the subject is to be introduced) and the activators (the conservation body undertaking the reintroduction). Second it must be of benefit to the subject species and/or the host ecosystem. The aim of this review is to discuss the extent to which the reintroduction of the Eurasian lynx to Scotland fulfils these criteria, and thus to consider whether, despite the length of its absence, the lynx has a potential role as *the* large carnivore of Britain. Before doing this it is necessary to summarise the natural history of lynx and the circumstances under which the species lived in, and was lost from, the UK.

THE BACKGROUND

Under Article 11 (2) of the European Union's Convention of European Wildlife and Natural Habitats, contracted parties, of which the British Government is one, should "encourage reintroduction of native species...when this would contribute to the conservation of an endangered species", conditional on a preliminary study to establish the likelihood of the reintroduction being "effective and acceptable." (Anon, 1979). Parties are next instructed to "strictly control the introduction of non native species." In neither the document nor its appendices is a definition of a native species given. What kind of criteria are being used to decide? It is clear from the quote above that contemporary residence is not a prerequisite, but is it a sufficient determinant?

Scottish Wildlife Trust (SWT), a major independent conservation organisation in Scotland, advocates complying with these recommendations. SWT does provide definitions of introduction and reintroduction. It is opposed to introduction, which it defines as "the intentional or accidental dispersal by human agency of a living organism outside its historically known native range". It is however cautiously in favour of reintroduction, which it specifies as - "The intentional movement of an organism into part of its native range from which it has disappeared or become extirpated in historic times as the result of human activities or natural catastrophes," (SWT, 2000).

These statements imply that residence in a country does not make a species native: a country's native animals are those which colonised independently. What is also apparent is that the return of presently absent native animals is desirable but non native arrivals are not welcome.

The modern flora and fauna of the Northern Hemisphere could only begin to establish themselves when temperatures climbed out of the lows of the most recent Ice Age, that is, no earlier than 12,000 - 10,000 bp. The final stadial (glaciation) of this last cold period came to an end about 10,000bp in Europe (Bell & Walker, 1992). The severing of the land bridge with Europe c.9500bp effected Britain's final isolation from the mainland (Yalden, 1999). To all intents and purposes, colonisation by terrestrial animals ceased, therefore the indigenous land animals of the island must have arrived before this event.

THE POTENTIAL INTRODUCTION OF THE LYNX AND OTHER MAMMALS

SWT, along with Scottish National Heritage and the Mammal Society, has approved plans for the reintroduction of the European beaver (*Castor fiber)* to Scotland in 2003 (Kitchener, 2002). Beavers are believed to have last existed in Britain in the fifteenth century (Kitchener & Bonsall, 1997).

The beaver will be the only mammal ever to be actively reintroduced to the UK. It is also the only native rodent species to have become extinct in Britain since the modern fauna became established (Kitchener, 2002). All three of our large carnivores, the wolf (*Canis lupus*), the bear (*Ursus arctos*) and the less widely known Eurasian lynx (*Lynx lynx*) were lost in historic times. The last Scottish wolf is recorded as being killed in the 1740s, three centuries after the beaver's demise but a plan to return wolves to Britain has never come near to the ratification stage. No one can deny that if the beaver is a native of the UK the wolf should be regarded as native also. The situation demonstrates the added cultural and practical complications of reintroduction when the subject is a carnivore. "Nativeness" is by no means the only criterion the species in question can be asked to satisfy.

Wolves, and to some extent bears, have received a great deal of negative publicity through the ages. A lynx reintroduction proposal is less likely to encounter opposition from people whose views are prejudiced by folklore. Compared with the much maligned 'big bad wolf', the lynx is little known and, therefore, a lynx reintroduction proposal is perhaps less likely to encounter opposition before it is even drafted.

The Eurasian Lynx, *Lynx lynx*, belongs to the cat family, Felidae. Felidae is one of the seven

families, which make up the order Carnivora. Also included in this order are the family Ursidae, which

Table 1. The Eurasian Lynx, *Lynx lynx*. Morphological and Natural History Variables

Body length	70-130 cm
Height to shoulder	60-75 cm
Weight	12-35kg, average weights: 18.1kg (female), 21.6kg (male)
Dental formula	I 3/3, C1/1, P2/2, M1/1
Coat	Yellow to brown showing seasonal and latitudinal change
Distinctive morphological features	Short tail with black tip, tufted ears, cheek ruffs, wide spreading paws
Life span	17 years in wild
Daily food requirement	1-2.5 kg
Gestation	63-73days
Litter no.	1-4 kittens, usually 2 or 3
Breeding frequency	1 litter per year

includes the brown bear, and the Canidae to which the wolf belongs. There is not complete consensus over the lower level systematics of the lynx. The system used here is in agreement with Council of Europe Action Plan (2000). This is to regard the lynx as a genus within the family Felidae with four species: the Eurasian lynx - *Lynx lynx*, the Bobcat – *L. rufus*, the Canadian Lynx – *L. canadensis* and the Iberian/Spanish Lynx – *L. pardinus*. *L. lynx* is often quoted as having several subspecies - the type occupying Northern Europe being *L. l. lynx* the boreal lynx. Some authorities include the Spanish lynx as one of these subspecies (*L l. pardinus*) (Kitchener, 1991). Other variations of the classification scheme include regarding *L. pardinus* and *L. lynx* as two of four species in the subgenus *Lynx* of the genus *Felis* (Nowark 1999; Corbet, 1991).

Although the lynx is not listed as endangered by Convention on International Trade in Endangered Species (CITES), the Council of Europe (CoE) maintains it is in need of conservation as a result of population fragmentation. The once pan-European species now exists in several relatively small isolated units. Small populations are generally felt to be less robust as there is a greater likelihood of any stress causing numbers to fall below the viability threshold. The loss of even one local population is unfortunate, but the more drastic consequence of such population structuring is that the species as a whole is at no less risk than the strongest of its isolated constituents. The CoE regarded the lynx situation as serious enough to merit including the species in "the Big Five" (brown bear, grey wolf, Eurasian lynx, Iberian lynx and the wolverine); predatory mammals who form the subject of their initiative aimed at maintaining and restoring the large carnivores of Europe.

It is true that Eurasian lynx become extinct from Scotland over a thousand years before the beaver, but how much importance should be put on this? At what point does the past become recent enough to be relevant? This is a question with no generally accepted answer. The major wildlife agencies do not attempt to answer it. Their primary concern when considering a reintroduction proposal is whether the species in question is more likely to enhance or to disrupt the ecosystem into which it is placed. They follow the International Union of the Conservation of Nature 1995 Guidelines for Re-introduction (Anon, 1995). These call for assurance that: a) there is a suitable source population which will provide animals of appropriate genetic make up without this source itself being compromised, b) an area of adequate size of suitable habitat and food resources is available, c) there are enough qualified staff to undertake the preliminary work, the actual introduction and subsequent monitoring, and d) the costs of all stages have been assessed. Where a species has been lost from an area in the distant past it must be possible to demonstrate using experience gathered within Europe, "that this species has an integral role in the relevant habitat".

THE BIOLOGY AND ECOLOGY OF THE LYNX

The Eurasian Lynx, *Lynx lynx*, is the biggest of the cats in the European region. Its large paws, thick coat and ear tufts are prominent characteristics of the genus Lynx. Table 1 shows other morphological data. At the full extent of its historical range there were populations in western and eastern European countries, much of the former USSR and as far as Iran and China (Alderton, 1993). This remarkably extensive range, one of the widest known for a cat species, spans many types of terrain. Lynx by preference frequent dense cover, but populations live successfully in a variety of habitats. In Europe they are found mainly in deciduous woodland or pine forest. In central Asia, however, they inhabit open, thinly wooded areas. The most northerly extent of their range includes landscapes of tundra and rocky slopes (Jackson, 1996).

Despite obvious morphological adaptation to cold and snowy climates the species is not restricted to high altitudes. In the Carpathians the highest density of the species is found between 700 and 1100 meters, but individuals occur as low as 150 meters. Reports of lynx living at heights of 2000m,

demonstrate the animal's ability to tolerate extreme environments (Bjarvall & Ullstrom, 1986).
An animal able to live successfully in a range of habitats must be capable of behavioural adaptability, as well as being physically robust. The wide geographical range of the lynx is more understandable when one appreciates that a description of the lynx ecology contains more preferences than absolutes. This facilitates the species' wide geographical range Tables 2 and 3 list estimated home ranges in different regions of the overall species' range.
Lynx are classed as nocturnal hunters, although they prefer to rest in the darkest hours and are most active in the hour before nightfall (Jackson, 1996; Burton, 1991). Like other felids, however, they rely on sight and sound when hunting and this practice is ineffective under conditions of poor visibility. Thus, in bad weather the lynx will resort to daytime activity (Kitchener, 1991).
Felids, to which the lynx belongs, are arguably the mammal group most highly adapted to meat eating (Gittleman, 1989). For them, as for all dietary specialists, lifestyle – how and where they live - is dominated by the availability of the appropriate food source in sufficient quantities. The other species in the genus lynx are specialist lagomorph hunters and it is often assumed the Eurasian lynx also relies on hare populations.
Unlike the Canadian lynx (*Lynx canadensis*), which preys almost exclusively on the snowshoe hare throughout the year, there is seasonal and regional variation in the *L. lynx* diet (Kloor, 1999). The

Table 2. Ranges of lynx from various types of terrain. (area in km_)

Source	Home Range		Territory (core area)	
	Male	**Female**	**Male**	**Female**
Council of Europe Action Plan 2000	180-27880	98-759		
Council of Europe Action Plan 2001	71-450	45-197		
Wild Cats of the World			200-400	100-150
Mammals of Britain and Europe	Few dozen km, central Europe to 1000km Scandinavia			
Cat Specialist Group IUCN (given as averages)	264 (n=23)	168 (n=64)	150 (n=58)	72 (n=27)

Eurasian lynx is the largest of the species and appears to be most successful when feeding on small ungulates (Jackson, 1996). In the Pan-Alpine conservation strategy for the lynx (Adamic et al, 2001), one section states "many items can be found in the lynx diet" and in another the lynx is described as having a "specialist prey requirement". This seems contradictory but not when data on lynx populations over the species' range are brought together.
Lynx specialise to the extent and in a manner that their local habitat allows. Populations take as their staple food the most abundant of a range of prey species. The relative abundance of the local 'favourite' item and the other potential prey species influences the extent to which the favoured item dominates the diet. In Scandinavia red deer (*Cervus elaphus*) form the bulk of the diet. In Switzerland chamois (*Rupicapra rupicapra*) and roe (*Capreolus capreolus*) constitute 85% of all catches. Roe are also the main prey item in the Carpathians. Although in areas where ungulates are scarce lynx are small and in less than peak condition, there is evidence that populations do exist, in north Finland and Siberia for example, where they have to live on a diet almost completely made up of lagomorphs (Jackson, 1996).
A specialized meat eater cannot supplement animal food with non-meat items, like berries and roots, a choice available to omnivorous carnivores such as the bears. A single lynx requires on average 1kg to 2.5kg of meat per day. Survival depends on getting access to a specific resource that requires substantial energy output to obtain. Lynx do this by defending a territory in which they have exclusive hunting rights. The result is a solitary existence. The only association that takes place among adult lynx occurs between males and females during mating periods. Two females never hold the same territory, although the territories of males can overlap.
Male territories are larger than those of females and can encompass parts of several females' territories. The absolute range of both sexes depends greatly on the productivity of the land on which they are residing. Where ungulates are at a high density, ranges are small. As ungulate density decreases ranges have to increase in size for a lynx to have access to sufficient resources. (Breitenmoser, 1998) (Table 2). Two points should be noted about the terminology used in Table 2. Firstly the home area is the area usually around the domicile over which an animal travels in search of food. Secondly, the territory applies to the area within the home range occupied more or less exclusively by an animal or group of animals of the same species and held through overt defence, display or advertisement (Burton, 1979; Bjarvall & Ullstrom, 1986; Kitchener, 1991; Alderton, 1993; Breitenmoser et al., 2000).

HISTORY OF THE LYNX IN SCOTLAND

There is a dearth of information about former British lynx populations. As with all prehistorically extinct species, period of residence can only be estimated. The oldest fossil find tells us only that the animal existed at this date. The most recent find indicates no more than that the animal was still present at this time.

The palaeontological record for Scotland in the Quaternary is not good. Ice covered the country during much of the Pleistocene and there is a shortage of suitable cave sites. The high acidity of the soil is another factor which mediates against fossilisation (Kitchener & Bonsall, 1997). Only one of the meagre number of lynx fossils found in the UK comes from a Scottish site (Kitchener, 1983; Yalden, 1999). Many British specimens come from sites of 18th and early 19th century excavations so were processed before expertise in recording fossil sequences and handling finds were well developed (Jenkinson, 1983; Kitchener & Bonsall, 1997). Most literature has dated lynx fossil finds by associated species with more complete records, and by the presence of artefacts associated with particular prehistoric cultures (Yalden, 1999).

It has been suggested that lynx were in the UK during the last cold stage (Guggesberg, 1975, quoted in Yalden, 1999). There is little fossil evidence for this. Of the fifteen British finds only four come from sites with pre-Flandrian (<10,000 year ago) sequences. At only one of these did Jenkinson (1983) in his review, regard the occurrence of lynx remains as a genuine indication of the species living contemporaneously with the other creatures present, rather than an artefact of geomorphological mixing or bad handling of recovery operations. Yalden (1999) suggested a postglacial arrival. Roe deer have a reasonable fossil record and some remains can be dated (pollen and carbon 14 dating techniques). They are believed to have entered Britain in the Mesolithic (c.10000-5000bp). It is likely that the lynx would have appeared around this time, obviously before the opening of the English Channel (Yalden, 1999). Sizable lynx populations prior to colonisation by small ruminants are known to have existed only in three areas, all in the northern part of the felid's range (Hedmark, Finland and Ural Mountains) (Breitenmoser et al. 2000).

The latest reliable record, according to Jenkinson (1983), comes from Steely Cave, Yorkshire, where a Mesolithic artefact was found and the pollen sequence matched that of zone VIIa (c. 7000-5000bp).

Subsequently, radiocarbon dating has been performed on a partial skeleton from Reindeer Cave, Inchnadamff, Sutherland, (formerly believed to be no more recent than pollen zone III – c.11,000-10,000 bp.). It was dated at c1880bp, indication of the species' survival in Scotland at least 3200 years after pollen zone VIIa.

The above section on lynx ecology emphasised the animal's ability to adapt its feeding strategy, range and diet depending on its circumstances. The precise nature of the previous British population must be assumed to depend on when it was resident, because the environment was changing over time. The late Devensian saw a rise in temperature above present day levels throughout Europe, but at the very end of the Pleistocene temperature fell once more (11,000-10,000bp). Ever since rapid climatic amelioration terminated the final stacial, (c.10,000bp), European temperatures have oscillated within a range rarely greater than 1-2° above or below present levels. Mid-July temperatures in late glacial were 7-9°. Mesolithic average July temperature was 15° (Bell and Walker, 1992).

The warming considerably altered the British landscape through its long-term effect on the vegetation. Pollen records show a trend of increasing forestation through most of the Mesolithic (c10,000-5000bp) (Price, 1983). The woodland matured and its constituents altered partly a result of adapting to fluctuating precipitation levels, which remained dynamic despite temperature stability.

Table 3. Densities of lynx in different habitats.

Area	Density (individuals/100km)
Poland	1.9-3.2
Switzerland, Jura mountains	0.94
Switzerland, North Alps	1.2
Switzerland, central Alps	1.43
South Norway	1
Sweden	0.34-0.74
Bialowieza	10-19
Russia	< 4

The modern habitat most similar to the British lowlands in the first half of the Flandrean is thought to be that of the Bialowieza forest, Poland (Yalden, 1999). Figures show Bialowieza to have the highest densities of lynx so far recorded (Cat Specialist Group web site). Table 3 shows how density varies from area to area. This is likely to be an indication of near optimum conditions. The 580km^2 forest provides a habitat of wide rivers, reed beds and lagoons. The rich landscape is able to support about 3700 red deer and 2700 roe, ample prey for the 19 lynx and around equal numbers of wolves believed to reside in Bialowieza (Yalden, 1999). Yalden (1999) calculated that at this density the whole of the UK (230,367km^2) could have

supported 7543 lynx. If he is correct Mesolithic British lynx were certainly not dwindling.

A British lynx extinction during the Mesolithic in Pollen zone VIIa does not have an obvious cause. Climate change alone does not seem a likely explanation (Yalden, 1999). The range of the Eurasian lynx spans an area over which the geographical temperature range is greater than the temporal variation Britain is thought to have experienced during the Mesolithic. It is likely the species would have had the capacity to cope with the altering temperature and weather conditions (Kitchener & Bonsall, 1997; Yalden, 1999).

The much more recent history of lynx decline on the continent gives clues as to the factors which are likely to undermine the species. During the eighteenth and nineteenth centuries deforestation to make way for an expanding agricultural industry drastically reduced the amount of natural woodland on the continent of Europe. The increasing human population overexploited what remained. This resulted in severe degradation of the lynx's preferred habitat. Since the lynx uses an ambush hunting technique, the percentage of attacks that are successful is highest in areas of dense forest (Breitenmoser, 1998). Deforestation has also directly influenced the contemporary fall in wild ungulates numbers. (Breitenmoser, 2000; Breitenmoser, 1998) Hungry predatory animals resorted to supplementing their diet with ungulates from the increasing domestic herds, thus farmers were added to gamekeepers and fur trappers as direct persecutors of the lynx.

Drastic reduction of woodland took place in Britain centuries before it became a major issue on the European mainland. Jenkinson's review reports of "woodland clearance by human groups" beginning at the end of the Mesolithic (Jenkinson, 1983). This substantiates his belief of a Mesolithic extinction of the lynx. However, Bell & Walker, (1992) while agreeing that clearance of woodland did take place in the late stages of the Mesolithic stated that the effect of hunter gathering societies on the landscape is limited to a local level.

At the very end of the Mesolithic the lifestyle of humans in Britain changed fairly abruptly from hunter to farmer. They then began to have a significant impact on the landscape (Bell & Walker, 1992). It is plasticity of lifestyle which allows the lynx to survive in areas less than ideally suited to its ecology. If the productivity of the habitat declines, the territory size of each lynx must increase if the animals are to survive. This will cause the population density to fall and eventually the population will become extinct. In prehistoric Britain the lynx would have been put under additional pressure as those animals on British soil turned into island populations, limiting the area available for expansion. Yalden (1999) suggests that the strain, when combined with hunting pressure, could have led to the lynx's disappearance from Britain. Thus it appears the survival of British lynx into the Neolithic is more understandable than its extinction before the end of the Mesolithic.

The latest data on the Inchmadamph skeleton suggest the lynx's time of residence could have extended into 'historic' times. This discovery has important implications for the debate on the wisdom of lynx reintroduction to Scotland. The time between the Neolithic and the Roman occupation was when the characteristic fauna of modern Britain developed. By the time of the Roman invasion, human clearance had transformed the island into what was essentially an agricultural landscape (Yalden, 1999).

DISCUSSION

In the introduction to this article I have stated my view of the requirements for a successful reintroduction. I then reviewed the biology and ecology of the lynx, and described the history of the lynx in Scotland. I now discuss the potential introduction of lynx to Scotland in more detail, and evaluate the extent to which founding a lynx population in Scotland fulfils the requirements and the Council of Europe's Action plan. I have divided the discussion into two parts – feasibility of reintroduction, and benefits of reintroduction.

Feasibility

Had climate change played a major role in the downfall of the British lynx population, reintroduction would be inappropriate and, most likely, impossible. The latest evidence, however, suggests lynx survived in Scotland into Roman times. This increases the legitimacy of arguments for the species' reintroduction to Northern Scotland because it implies that maintaining a lynx population in modern Britain could be ecologically viable and there could be a niche in our ecosystem for these cats. Something other than unsuitable natural habitat must therefore have been responsible for the loss of the species from Britain. One recommendation of Council of Europe's 2000 action plan is that "The historical decline of the lynx should be analysed, the threats to the population identified and measures to remove limiting factors taken." (Breitenmoser, 2000). In the case of the British lynx this would be a more complex task, since the period under investigation would be the ancient rather than the recent past. The century, and therefore the environmental conditions, in which the lynx perished are rather uncertain. Investigation of the history of the lynx in Britain is a crucial part of piecing together the circumstances of its demise, but one cannot simply extrapolate from this to the steps required to allow its return. Examination of the way in which modern day lynx are faring in various types of habitats and the success or otherwise of management and conservation can provide some information.

The European *Lynx lynx* population reached an all time low on the continent in the 1950s and '60s. At this time it was extinct from south, west and northern countries, remaining only in Fennoscandia (Norway, Sweden, Finland), the Eastern

Carpathians and White Russia (present day Belarus), (Bjarvall & Ullstrom, 1986). Lynx reintroduction programmes began in the 1970s but conditions had begun to recover before this (Breitenmoser, 1998). By the end of the nineteenth century authorities had started to appreciate the environmental importance of forest regeneration (Breitenmoser, 1998). As conditions improved ungulate numbers recovered. The lynx was able to recolonise parts of its former range. Recovery was aided in many countries by the introduction of legal protection (Breitenmoser et al. 2000).

Alderton (1993) noted that only three of nine reintroductions appeared to have been viable in the long term, two Swiss projects (Dinaric population, Alpine population) and the Slovenian (Carpathians) programme Successful introductions have been in areas of dense forest and high ungulate density. Of the ten recognised European populations only two do not cross national boundaries. Pan-European collaboration on the regeneration of Europe's carnivores means lynx can move freely over vast tracts of land. The forests of Britain were decimated long before their importance was appreciated and earlier than those in most mainland European countries. Serious attempts at reversal began later. All the evidence suggests that successful reintroduction requires forestation or other suitable cover over a sufficient area and, certainly in the early stages, legal protection and population monitoring.

Even if Britain were to sign up to the Action Plan of the Council of Europe a UK population would remain insular. The importance of this is made apparent by the knowledge that some small countries in mainland Europe do not have sufficient area to support an independent population. In addition, where reintroduction has been tried in areas where natural recolonisation is not a possibility, the amount of work required is even greater and success is even less certain (Breitenmoser et al., 2000).

Rural Britain is does not lack areas where the concentration of deer should be adequate to support a reasonable number of lynx (Yalden, 1999). Suitably sized sites of dense, upland forest are more limited. Scotland is better endowed with appropriate expanses than England.

More effort would have to be put into reforestation, specifically expanding existing woodland sites, if a population of lynx in Scotland was to have a chance of becoming ecologically feasible.

The next issue is how well such a population could coexist with the resident Scottish biota. Of particular importance is whether the introduction of a large predator would lead to competition with the present Scottish carnivores, and how our deer populations would respond to a serious wild hunter.

The member of our fauna most closely related to the lynx is the Scottish wild cat *(Felis silvestris grampia)*. It might be expected therefore that wild cats would be the indigenous carnivores put at greatest risk by a lynx return. Wildcats are protected under a schedule of the Wildlife and Countryside Act 1981. Any venture that could threaten them is likely to meet with strong opposition from many conservationists. Although wildcats inhabit most of the same general parts of the continent as lynx, they are by and large at lower altitudes (<500m) and catch only smaller prey items (Corbet and Harris, 1991). None of the literature cited here on lynx reintroduction mentions significant competition between the two species. It seems therefore, the Scottish wildcat and the lynx could coexist as part of a carnivore guild, provided that deer did not become scarce.

There is no consensus on either the extent or the nature of the lynx's effect on wild ungulates. In a review of the lynx in Switzerland, Breitenmoser (1998) stated that on fairly barren territory lynx home ranges are large and not a major factor in determining the number of small ungulates: where prey is plentiful lynx hunting in a concentrated area can significantly shrink populations of deer at a local level. Other reports, cited in the Council of Europe's Action Plan for the Lynx, (2000), suggested that it is at the margins of ungulate ranges where population is least dense that lynx predation most greatly disrupts ungulates. It appears that the results of predation are heavily dependent on the structure of the ungulate population, but the relationship is not straightforward and other factors are also involved (Breitenmoser et al., 2000).

The human species is itself a member of an area's biota. The manner in which the people of Britain would receive the lynx is hard to determine. Ultimately, it could tip the balance between the success or failure of the venture. On the continent the anthropogenic difficulties faced by large predators are most acute where they are reintroduced into areas from which they have long been absent. The largest difficulties are where sheep are left to graze unattended (Breitenmoser, 1998). This is the practice in Britain.

Presenting humans as 'just' another member of the biota is misleading. Apart from the magnitude of our influence, the most important feature is that our perception of the effect another creature has on us is as influential as the effect itself. Definite evidence that lynx in Scotland would threaten the welfare or economic interests of the Scottish people is scarce: the threat which human hostility could pose to the successful reintroduction of the species to Scotland is very real.

The first stage of any reintroduction must be a feasibility study (Breitenmoser et al., 2000). Certain conditions are made apparent by the above. A lynx population would have to be confined to a designated area which must contain sufficient resources to sustain the population without the area being compromised in any way. The site would have to be located so that conflict between people and the lynx was minimised and road casualty, a major cause of death of reintroduced lynx,

(Jackson, 1996; Council of Europe, 2000) avoided as far as possible.

If this information can be simplified into a set of fundamental requirements computer modelling techniques can be used to provide information which helps in the planning the venture. Geographic Information System (GIS) is an analysis technique which can determine the number of sites, in designated size categories, available in the study area (Scotland) and how many animals each could support. If supplied with the necessary biological variables PVA (population viability analysis) programmes allow an estimation of the likely number of release animals required if there is to be reasonable certainty of the population surviving on average for a specified length of time A 95% chance of survival for at least 50 years was the level used by Leaper et al. (1999).

The lynx is not an endangered species but, as has been mentioned, many populations in Europe are felt to be vulnerable. The source animals for the reintroduction of a British population would need to be taken from an area where density was reasonable and not in decline. With reintroduction of a long absent species there is not, as there is with population supplementation programmes, the danger of contaminating an indigenous subspecies with another subspecies. However, it would be judicious to use source animals from an area with similar ecology to the terrain being repopulated.

Much depends on the value organisations such as SWT would place on returning the lynx to Britain and how it would rate in importance relative to their other commitments.

Benefits

A primary purpose of the CoE in reintroducing lynx to places they formerly inhabited is the establishment of viable populations or sub-populations of viable metapopulations. Returning the lynx in Scotland would have very little impact on the success or failure of the redevelopment of a pan-European population. So such an action would be of negligible benefit to the species as a whole

If one's only concern were the welfare of the species, returning it to Scotland would be a waste of human and financial resources. Given the potential disruption to the source population, it could be seen as counterproductive. As a component of an action plan with the aim of improving the host ecosystem, however, it could be extremely useful.

The pattern in Britain, common to most areas of significant human colonisation, has been to increase ungulates numbers, which are a source of food and a focus of sport. The large carnivores, potential competitors for game, are persecuted. The natural equilibrium is destroyed and not allowed to redevelop. The red deer population now numbers c.300,000. Their browsing causes economic and environmental damage, and the food requirement of the increasing population is beyond the capacity of the available habitat (SNH web site). Insufficient nutrition can compromise the health of all age groups in the herds. Culling measures have so far been insufficient to halt the escalation. The presence of lynx is not suggested as a complete solution, but reintroduction of a natural predator is a measure so far untried, which could assist deer regulation.

Lynx have had much less effect on sheep populations than either bears or wolves in Europe and they never attack cattle (Breitenmoser, 1998). They are the most likely of the three to remain in remote areas and thus least likely to inhabit areas close to human settlement. On the continent they are not even perceived as 'man eaters', which both the bear and the wolf often are (Yalden, 1999).

A proposal has been put forward for setting up a lynx population on the Island of Rum (Nevard & Penfold, 1978). Manufacturing an artificial community on an island without requiring attitudes to alter would not greatly broaden our understanding of the changes that would be required to make the countryside of the Scottish mainland suitable for a functional lynx population.

Large predators are "keystone species'. They are the top of the food chain so their survival depends on the lower level of the chain functioning well. Investigating the viability of establishing a modern day British lynx population, even if the conclusion was not in the affirmative, would be a worthwhile exercise. The presence of a healthy lynx population is indicative of a healthy ecosystem. Aiming to create 'a lynx friendly environment', however slight the chances of complete success, would benefit a substantial proportion of the resident Scottish biota.

CONCLUSION

The lynx would not enter the minds of most British people should they ever be asked to name the creatures of the country's wilder past. Yet the Eurasian lynx is indeed native to Britain, in the sense that the species colonised this island independently during the Mesolithic, before Britain became separated from Europe (c9500bp). Recent work done on the Inchmadamph skeleton dated it at c1880bp and suggests the species survived in Scotland into historic times – post the Roman invasion of Scotland (c.43 bp). With this knowledge it seems more likely that the reintroduction of the lynx to Scotland would conform to IUCN criteria designed to ensure projects do not undermine donor populations or host ecosystems.

Its ability to hunt in different ways, combined with a tough physique, allowed the lynx to become one of the most widespread of the Felidae. These same characteristics make it quite possible that the species could find food and survive in the Scottish climate. There is no resident native British carnivore that would be at risk of intense competition for resources with the lynx. Even wild cats and foxes, the largest of our present carnivores, are much smaller and foxes are considerably more inclined to be omnivorous.

Interested parties are not in agreement over whether lynx are likely to prey intensively on livestock. Evidence does suggest that of the three possible candidates for reintroduction of a large carnivore to Britain, wolf, bear and lynx, the lynx is the least liable to cause a serious problems to farmers.

The conclusion that lynx reintroduction is theoretically feasible is not in itself justification for undertaking a scheme. A major objective of CoE lynx initiatives is the establishment of populations that contribute to the stability of metapopulations. Returning the lynx to Scotland would not significantly further this aim. It would create yet another discrete population, and in this case, there would not be the possibility of eventual amalgamation with populations in neighbouring countries.

Unlike the projects on the continent, the primary benefit of restoring a Scottish lynx would be for the existing fauna of the host country rather than for the lynx itself. We live in a country where forests and wild areas were removed to make way for agriculture. The wild animals have all been affected to a greater or lesser extent by habitat destruction. In addition game species have been encouraged, resulting in great rises in numbers of individuals. Meanwhile predators have suffered persecution and the outcome is the disappearance of all large carnivores. An investigation into the adjustments in land management necessary to enable a reintroduced population of lynx would highlight problems that directly and indirectly compromise many of our indigenous species.

The first is whether sufficient suitable habitat exists, or could be created, in Scotland to sustain a viable population. The second issue is anthropogenic difficulties, such as the widespread perception that the introduction of a large carnivore will inevitably cause major disruption.

With the present climate being relatively favourable to the general idea of reintroduction it would seem an appropriate time to investigate seriously the return of the lynx to Scotland. Bearing in mind the potential problems mentioned above, however, it is crucial that a feasibility study puts emphasis on determining how many lynx could be expected to live in the country, and whether it would be possible for British people to coexist with a major predator population without the much feared side effects.

REFERENCES

Adamic, M., Breitenmoser-Wursten, C., Breitenmoser, U., Fasel, M., Huber, T., Kaczensky, P., Koren, I., Molinari, P., Molinari-Jobin, A., Rotelli, L., Stahl, P., Stanisa, M., Vandel, J. and Wolfl, M. 2001. Pan-Alpine Conservation Strategy for the Lynx. *Convention on the Conservation of European Wildlife and Natural Habitats*. Council of Europe, Strasbourg.

Anon. 1979. Convention on the conservation of European Wildlife and natural habitats. 19.IX.1979, *European Treaty Series/104*, Bern.

Alderton, D. 1993. *Wild Cats of the World*. Blandford, London.

Bell, M. and Walker, M.J.C. 1992. *Late Quaternary Environmental Change: Physical and Human Perspectives*. Longman, Harlow.

Bjarvall, A and Ullstrom, S. 1986. *The Mammals of Britain and Europe*. Croom Helm, London.

Breitenmoser, U. 1998. Large predators in the Alps: the fall and rise of man's competitors. *Biological Conservation* 83, 279-289.

Breitenmoser, U., Breitenmoser-Wursten, Ch., Okarma, H., Kaphegyi, T., Kaphegyi-Wallmann, U. and Muller, U.M. 2000. Action plan for the conservation of the Eurasian Lynx in Europe. *Nature and Environment Series* 112: 1-69, Strasbourg, Council of Europe.

Burton, R. 1979. *Carnivores of Europe*. Cox & Wyman, London.

Corbet, G.B. 1984. *The Mammals of the Palaearctic region: A Taxonomic Review*. British Museum, Natural History, London.

Corbet, G.B. and Harris, S. 1991. *The Handbook of British Mammals* third edition. Blackwell Scientific Publications, London.

Gittleman, J.L. 1989. *Carnivore Behaviour, Ecology and Evolution*. Chapman & Hall, London.

Jackson, P. and Nowell, K., 1996. Wild Cats: a status survey and conservation action plan. IUCN, Gland, Switzerland.

Jenkinson, R.D.S. 1983. The recent history of northern lynx, (*Lynx lynx, Linne*) in the British Isles. *Quaternary Newsletter* 41, 1-7.

Kitchener, A. 1991. *The Natural History of the Wild Cats*. Christopher Helm, London.

Kitchener, A.C. 2002. Alien mammals: wreaking havoc or missing the boat? *Glasgow Naturalist*, 23, Supplement.

Kitchener, A.C. and Bonsall, C. 1997. AMS radiocarbon dates for some extinct Scottish mammals. *Quaternary Newsletter* 83, 1-11.

Kloor, K. 1999. Lynx and biologists try to recover after a disastrous start. *Science* 285, 320-321.

Leaper, R., Massei, G., Gorman, M.L. and Aspinall, R. 1999. The feasibility of reintroducing Wild Boar (*Sus scrofa*) to Scotland. *Mammal Review* 29, 239-259.

Nevard, T.D. and Penfold, J.B., 1978. Wildlife conservation in Britain: an unsatisfactory demand. *Biological Conservation* 14, 25-44.

Nowark, R.M. 1999. *Mammals of the World 6th Edition (Vol I)*. Baltimore and John Hopkins University Press, London.

Price, J.R., 1983. *Scotland's Environment during the Last 30,000 years*. Scottish Academic Press, Edinburgh.

Reintroduction Specialist Group. 1995. IUCN/SSC Guidelines for Re-Introductions. IUCN Species Survival Commission, Gland, Switzerland..

Scottish Wildlife Trust, 2000. *Policy on Introductions, Re-introductions and Translocation of Species*. Scottish Wildlife Trust, Edinburgh.

Yalden, D.W. 1999. *The History of British Mammals*. T & A.D. Poyser, London.

Web Site

SNH web site: http://www.snh.org.uk/

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 59-63.

A FORMER WATER-MEADOW IN THE UPPER CARRON VALLEY, STIRLINGSHIRE

John Mitchell

22 Muirpark Way, Drymen, Glasgow G63 ODX

"The meadows are filled with every kind of field herbs, and watered with perennial streams".
Sir John Clerk of Penicuik (1679-1755)

INTRODUCTION

The paper describes an investigation into a former water-meadow in the Upper Carron Valley, Stirlingshire. Until it was briefly uncovered by an exceptional fall in water level during the late summer of 1984, the site (NS 6885) had lain submerged by the Carron Reservoir (Fig. 1) since 1939. At over 250 ha, the Carron Meadow is reputed to have been the largest of its kind in Scotland.

BACKGROUND TO WATER-MEADOWS IN SCOTLAND

Two hundred years ago water-meadows were attracting considerable attention from agriculturists in Scotland, but today their creation and use is a virtually forgotten episode in the country's agrarian history. A water-meadow is defined as a grazing or hay field over which flowing water - often-silt-enriched - can be fed by a network of carefully graded channels. Equally important, a water-meadow can be laid dry at will. Following irrigation in spring such a meadow undergoes rapid growth, providing a much needed 'early bite' for overwintered stock. The meadow would then be closed to animals, any trampling damage to the channels repaired and the vegetation watered again before being left to grow on as hay. After the hay crop was cut and gathered in, the meadow was watered once more, offering fresh grazing in late summer at a time when the drier grasslands on the farm were past their nutritional best. To judge from papers (e.g. Singers, 1807) published in the early *Transactions of the Highland Society of Scotland* and contemporary county agricultural reports, the peak period in the laying-out of water-meadows in Scotland was from the end of the 18th century into the early part of the 19th century. This was a time of enhanced prices for farm products, a direct result of the drawn out war with France. Although poorly documented, there does appear to have been a slightly earlier phase of water-meadow use in Scotland, of which the Carron Meadow may have been part.

MAPS AND DESCRIPTIONS OF THE CARRON BOG OR MEADOW

Along with the rest of the county, the Carron Valley was surveyed by the military sometime between 1749-1751. On the resultant 1:36,000 unpublished Roy map of Scotland, the Carron Bog or Meadow appears as the upper flood plain of the Water of Carron. Thirty years or so later, the same area is shown with the caption 'a fine meadow' on Charles Ross's 1:63,360 Map of Stirlingshire issued in 1780.

Not until the end of the 18th century and the publication of the first *Statistical Account of Scotland* is there a description of the Carron Bog or Meadow. In his contribution for the Parish of Fintry, the Reverend Gavin Gibb (1793) wrote ..... "The [River] Carron rises in the west end of the parish, and runs east in a straight direction, watering the Carron Bog in its passage". In giving the dimensions of the Carron hay-meadow, which the Reverend Gibb considered the largest in Scotland, he also included parts which extended into two neighbouring parishes ..... "Beginning in [the parish of] Fintry, it runs east between the parishes of Kilsyth and St. Ninians to the extent of 4 miles (6.44 km); is in some places 2 miles (3.22 km) in breadth, and in no place less than 1 mile (1.61 km); containing about 500 [Scottish] acres (630 English acres / 255 hectares) in one continuous plain. It affords sustenance during the winter to cattle of the surrounding farms. This remarkable meadow, besides its utility, adds great liveliness to the general face of the country. The scene it exhibits during the months of July and August, of 20 or 30 different parties of people employed in hay-making, is certainly very cheerful. And during winter, the greater part of it being overflowed by the Carron, which runs through the middle of it, "*which is then industriously led over the whole extent*" (present writer's emphasis). This latter statement would appear to confirm that a system of water-meadow management was in operation in the Upper Carron Valley.

John Grassom's 1:42,240 map of the *County of Stirling* (1817) is of interest from the aspect of river engineering. It shows that, compared with the Roy and Ross maps of the previous century, the meandering stretch of the River Carron running through the western part of the bog or meadow had been straightened out, presumably to improve water flow.

The *New Statistical Account* for the Parish of Fintry (Smith, 1841) includes the following footnote on the Carron Meadow ..... "The most abundant source of meadow hay is the Carron Bog, an immense tract of meadow land on the banks of the River Carron, commencing in [the parish of] Fintry, and thence passing into Kilsyth and St. Ninians. The meadow extends in length fully 3 miles (4.38 km) and averages in breadth about 400 yards (366 m), though in some places its breadth is little short of 1 mile (1.61 km). It contains 358 acres (145 ha)". The reason for the apparent shrinkage of the Carron Bog or Meadow is made clear with the publication 20 years later of the Ordnance Survey 1:2.500 map and accompanying Book of Reference covering the area. The original marshy ground was sufficiently agriculturally improved since conversion to water-meadow, that it had been found practicable for the best drained land to be put to the plough. Rotational cropping adopted by that time included

Fig. 1. Looking south: the western end of the Carron Reservoir, Stirlingshire.

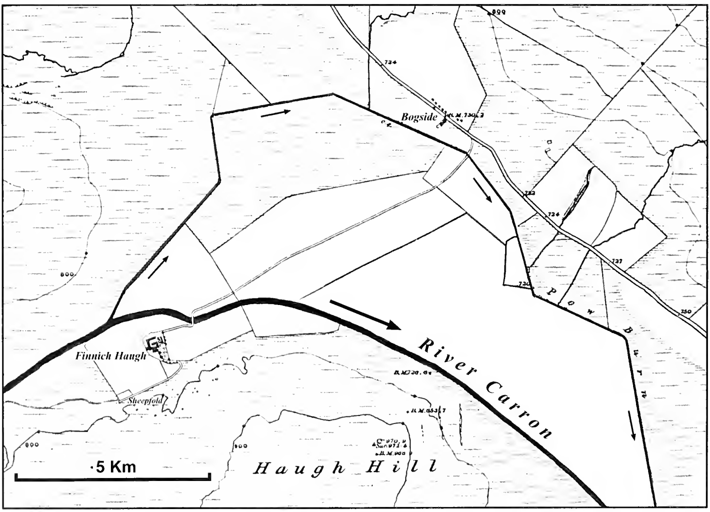


Fig. 2. Ordnance Survey map of the Upper Carron Valley in 1860.

Fig. 3. Looking south-east: internal water channels of the former Carron Water-meadow.

Fig. 4. Looking north-east: internal water channels of the former Carron Water-meadow.

cultivated varieties of grass suitable for hay. Also shown on the OS map is the water-meadow's main water carrier diverting from the River Carron at Finnich Haugh (the farm steading later renamed The Binns), which then contoured the Carron-Endrick watershed in order that water could be gravity fed into the meadow from the opposite side of the valley (Fig. 2). In common with all water-meadows, a gentle declivity to the water carrier was essential to prevent the outlet sluices onto the meadow becoming continually clogged with moving gravel. Significantly, the name Pow Burn given to the feature implies a slow-running water-course.

As part of a nationwide project, an agricultural assessment of Stirlingshire was undertaken in the 1930s, fortuitously just before most of the low-lying farmland in the Upper Carron Valley was flooded following the construction of a reservoir. The field by field survey showed that rotation grass for hay was still one of the principal crops of the district (Stamp, 1946).

THE CARRON RESERVOIR

The feasibility of siting a reservoir in the Upper Carron Valley was first considered at the turn of the 19th century by the Carron Iron Company. Founded in 1759 alongside the lower reaches of the River Carron, the iron works was beset with water shortages during the drier summer months almost from the start. The problem was exacerbated in 1790 with the opening of the Forth and Clyde Canal, which in its Bonnybridge stretch depended on one of the main tributaries of the River Carron for its water (Campbell, 1961). Several sites for additional water storage were investigated by the Carron Company, including the Upper Carron Valley. According to a communication from the Reverend John Graham - the Minister for Fintry 1805-1822 - the local residents successfully raised an objection to the Carron Valley scheme on the grounds that their hill farms would be rendered unviable without the hay they harvested from the low-lying meadowland (Stirling, 1817).

Faced with the increasing need for additional water supplies for domestic and industrial use within their district during the early 1930s, the Stirlingshire and Falkirk Water Board promoted a plan for a major new reservoir in the Upper Carron Valley. It was to be an unusual undertaking in that the proposed site straddled the central watershed between East and West Scotland, the reservoir requiring a dam at both ends. Parliamentary approval for the scheme was given in June 1935. Four years in its construction, the Carron Reservoir was formally opened on 14 July 1939 (Anon, 1939). At 5 km long, an average of 0.78 km wide and a surface area of 388 ha, the reservoir covered almost the entire floor of the Upper Carron Valley. Some of the dispossessed farm owners did however, continue to work the meadows for hay until the land was actually submerged; and at least one was still utilising the network of channels for watering his cultivated grass crop right up to the end (Mitchell, 1997), seemingly the last known instance of water-meadow management in Central Scotland.

Further demand for water in the newly created Central Region administrative area led to an enlargement of the Carron Reservoir in the mid 1980s. The top water level at the east dam's overflow sill was raised by about 0.5 m, the upgrading operational by the winter of 1987/88.

THE SITE OF THE CARRON WATER-MEADOW EXPOSED

A visit to the Upper Carron Valley was made by the author in the late summer of 1984 on being informed that the level of the reservoir was abnormally low. The surface level had initially been dropped to facilitate structural alterations to the two dams (Dr.A.B. Bailey pers comm), but this was then followed by an unusually prolonged period of low rainfall (Harrison, 1987). The overall result was a lowering of the reservoir's water level by an unprecedented 4.98 m, a situation which more or less continued to the end of September.

Examination of the western end of the receding reservoir confirmed two features already noted on 19th century maps. First was the channelised section of the River Carron, which on inspection was found to have been faced with timbers to strengthen the re-aligned banks. Second was the line of the main water carrier, which led off the River Carron and circled around the Carron-Endrick watershed to eventually rejoin the river further downstream. Not shown on any published map, however, was any evidence of a series of internal channels which, in a water-meadow, would have been necessary to distribute the water evenly over the ground. Despite a subsequent history of arable ploughing, the lay-out of the internal water channels was still visible on the drying-out bed of the reservoir (Figs. 3 & 4).

Following the onset of the autumn rains, the water level gradually rose and the site of the old water-meadow was once more lost to view. With the capacity of the reservoir substantially increased since the study was carried out in 1984, it would seem that only in very exceptional conditions will this intriguing piece of Stirlingshire's agricultural history be so fully revealed again.

THE ORIGINAL VEGETATION OF THE CARRON BOG OR WATER-MEADOW

To the naturalist-historian, a question raised by this investigation is: what was the Carron Bog or Meadow's natural vegetation before the land was agriculturally improved in the 19th century?. One indication is to be found along the River Carron's ungrazed banks just downstream of the east dam. Seen to advantage beside the Forestry Enterprise riverside car park and picnic area, the plant assemblage is typical of northern tall-herb wet meadows formerly cropped for marsh hay, with globe flower *Trollius europeus*, ragged robin *Lychnis flos-cuculi*, large bitter cress *Cardamine amara*, meadowsweet *Filipendula ulmaria*, water avens *Geum rivale*, wood cranesbill *Geranium sylvaticum*, angelica *Angelica sylvestris* and water

sedge *Carex aquatilis* well represented. Except where a vigorous growth of reed canary-grass *Phalaris arundinacea* has overtaken the community, there are no dominant grass species present. Cooper & MacKintosh (1996) have recommended that this type of riparian tall-herb assemblage be treated as a variant of *Filipendula ulmaria - Angelica sylvestris* mire M27 (see Rodwell, 1991) in the National Vegetation Classification.

ACKNOWLEDGEMENTS

In carrying out the field work for the above project, I am grateful to Central Region Council Water & Drainage Department and the Forestry Commission for granting me access to the Carron Reservoir and surrounding area during the summer of 1984. My thanks also to Frank Stone of Scottish Water for providing additional information on the enlargement of the reservoir in the mid 1980s. Mary Bruce of the Drymen and District Local History Society kindly commented on the first draft of the paper, and Norman Tait prepared the accompanying map and figures for publication.

REFERENCES

Anon (1939). *Carron Valley Reservoir* [commemorative booklet]. Stirlingshire & Falkirk Water Board.

Campbell, R.H. (1961). *Carron Company*. Oliver & Boyd, Edinburgh.

Cooper, E. & MacKintosh, J. (1996). *NVC Review of Scottish Grassland Surveys*. Scottish Natural Heritage, Battleby.

Gibb, Rev.G. (1793). 'Parish of Fintry' in *The Statistical Account of Scotland* Vol.11, pp.371-382. William Creech, Edinburgh.

Harrison, S.J. (1987). Annual Climatological Bulletin No.6,1984. *Forth Naturalist and Historian* 9, 3-24.

Mitchell, J. (1997). Wet Meadows in Lowland West Central Scotland - an almost forgotten Botanical Habitat. *Botanical Journal of Scotland* 49, 341-345.

Rodwell, J.S. (1991). *British Plant Communities* Vol.2, *Mires and Heaths*. Cambridge University Press.

Singers. Rev.W, 1807. General Observations on the Practice and Principles of Irrigation.
Prize Essays and Transactions of the Highland Society of Scotland 3, 224-256.

Smith, Rev.W.G. (1841). 'Parish of Fintry' in *The New Statistical Account of Scotland* No.32, pp.38-47. William Blackwood, Edinburgh.

Stamp, L.D. (1946). 'Stirlingshire' in *The Land of Britain* Pt.23, pp.355-378. Geographical Publications, London.

Stirling, Rev.W.McG. (1817). Nimmo's *History of Stirlingshire* (2nd ed.). Andrew Bean, Stirling.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 65-68.

LOCH LOMONDSIDE DEPICTED AND DESCRIBED
5. EARLY NATURAL HISTORIANS

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 ODX

"I have taken the Loch Lomond district as my special charge, for I feel convinced if we are ever to have a perfect knowledge of the bird-life of this country, it is only by having many workers, and by each worker having a special district. In this way scraps of information, which would otherwise be passed over, are secured, and these, when published, in due time become of value."

James Lumsden (1882).

INTRODUCTION

To ascribe a starting date to natural history recording on Loch Lomondside is no easy task. The 12th century chronicler Geoffry of Monmouth's colourful tale of sixty so-called 'eagles' nesting on rocks in and around Loch Lomond (Giles, 1842) is but an oft-repeated legend that cannot be taken at face value. On the other hand, the 16th century map-maker Timothy Pont's comments on the yews *Taxus baccata* of Inchlonaig, fallow deer *Dama dama* on Inchmurrin and adders *Vipera berus* on several other islands in the loch (Mitchell, 1907) are apparently based on personal observations in which one can have more trust. From the mid-18th century onwards both travelers and local residents with a background of scientific investigation or the collecting of trophy specimens began to take an increasing interest in the Loch Lomond area, and equally importantly committed their findings to print. Which of these early naturalists should be chosen to head a short paper such as this inevitably comes down to personal choice, but most biographers would agree that the first person to visit Loch Lomondside for the express purpose of biological recording was the Reverend John Lightfoot; and it is with his botanical exploration of Scotland that this account begins.

John Lightfoot (1735-1788)

Intent on collecting material for the first-ever flora of Scotland, the Reverend John Lightfoot - Chaplain to the Dowager Duchess of Portland - accompanied the antiquary Thomas Pennant and his illustrator on a summer tour of the country in 1772 (Bowden, 1989). Reaching Drymen manse on their approach to the Highlands early on 13th June, it is generally assumed that it was at this point in the journey where they were joined by the Reverend John Stuart, a newly qualified Church of Scotland minister who was to act as their gaelic interpreter and guide. While Pennant was taking in the view of Loch Lomond, the two divines spent a productive day botanising Ben Lomond, recording not only flowering plants, but cryptogams as well. When *Flora Scotica* (Lightfoot, 1777) first appeared it was initially badly received. As Thomas Pennant observed ... "No sooner did it come out, than Envy emptied her whole quiver" ... and the two-volume work was quietly withdrawn and not re-issued until 1789. However, the Flora was not as widely condemned as the criticism would lead one to believe. The University of Glasgow, for example, offered John Lightfoot a doctorate in recognition of his outstanding achievement, an honour he modestly declined.

John Stuart (1743-1821)

The Reverend John Stuart first came to prominence in scientific circles as the traveling companion to Thomas Pennant and the Reverend John Lightfoot during their tour of the Highlands in 1772 (see above). As a botanist, John Stuart's knowledge of the Scottish mountain flora was almost without equal, with a string of first British records to his credit (Mitchell, 1986 & 1992). Later, in the resident minister's description of the Parish of Luss (Stuart, 1796) for the first *Statistical Account of Scotland*, he provides us with a tantalising glimpse of his other natural history interests. Over 100 different species of birds, 21 mammals, 13 fishes plus 6 reptiles and amphibians are tabulated, a commendable total considering the indifferent quality of the identification books of the time.

David Ure (1749-1798)

The Reverend David Ure was yet another cleric who was drawn to the natural world. For much of his ministerial career, Ure was only able to secure assistant posts, but this did present him with the opportunity of accepting commissions from Sir John Sinclair to work on the first *Statistical Account of Scotland* and compile agricultural reports for several Scottish counties (Burns, 1993). As the stand-in contributor of the Parish of Killearn description (Ure, 1795) for the *Statistical Account*, he was not in the same position as the Reverend John Stuart in being able to produce long species lists built up over a period of time, but his experience did enable him to pick up on several worthwhile records for the area which might otherwise have been overlooked. One of these was Loch Lomondside's last pair of lowland golden eagles *Aquila chrysaetos* nesting on the north face of the Campsie Fells. David Ure also noted that Finnich Glen was a haunt of the wild cat *Felis catus*, the animal's former presence at this lowland locality still recalled in the place name Craighat (Creag a' Chait). There are a few additional natural history snippets to be gleaned from his *General View of the*

Agriculture in the County of Dumbarton (Ure, 1794). Included amongst them are references to the fallow deer herds on Inchlonaig and Inchmurrin, together with local uses made of certain wild plants.

John Colquhoun (1805-1885)

John Colquhoun's father was Sir James Colquhoun of Luss, who had inherited the family estate on Loch Lomondside in the same year as the birth of his son. Colquhoun's passion for the outdoors began early, but it was not until 1833, when he gave up a military career, that he was able to devote a great deal of his time to hunting, shooting and fishing, together with assembling of a comprehensive collection of stuffed mammals and birds (Maitland, 1908). As a writer, Colquhoun published the first of several semi-autobiographical works in 1840. These he brought together as a 4th edition of *The Moor and the Loch* (Colquhoun, 1878), which is still considered a minor classic. The content includes vivid descriptions of field sports of the period, from wildfowling on Loch Lomond to ptarmigan *Lagopus mutus* shooting on the surrounding hills. Particularly revealing is Colquhoun's account of his participation as a youth in the destruction of all birds and beasts of prey considered to be a threat in the rearing of game. In older and wiser years, however, he not only championed the greater importance of good habitat, but the necessity of predators to ensure healthy stocks of red grouse *L. lagopus*. In such views John Colquhoun was away ahead of his contemporaries.

John Hutton Balfour (1808-1884)

In 1841, John Hutton Baltour was appointed to the Chair of Botany at the University of Glasgow, but remained only four years before returning to his native Edinburgh as Professor of Botany at the University and Keeper of the Royal Botanic Garden (Bettany, 1908). Although his term of office at Glasgow was brief, Balfour extended the practice started by his predecessor Professor William Hooker of summer field trips for the botany students. Even before the advent of railways, most of Loch Lomondside was accessible to excursionists because of the regular steamer services on the River Clyde and the loch itself. John Balfour's detailed field note books for 1846-1878 - extracts of which were published posthumously (Balfour, 1902) - show that even after moving to Edinburgh he continued to undertake botanical recording visits to the Loch Lomond area. With Ben Vorlich and Glen Falloch conveniently to band, the Inverarnan Hotel at the loch's steamer terminus was a popular base for Professor Balfour's student parties.

Robert Gray (1825-1887)

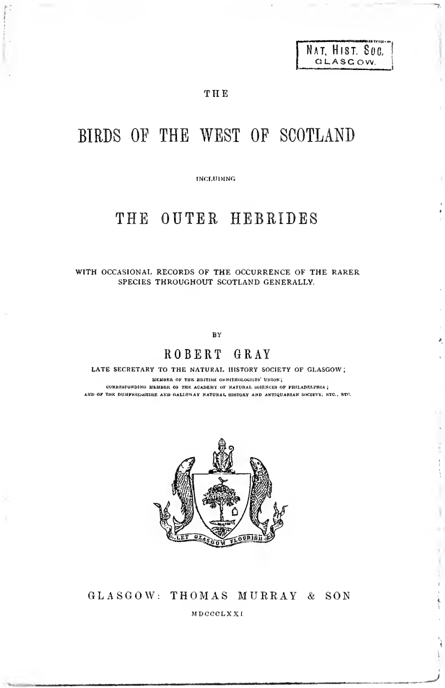
Robert Gray's long connection with west central Scotland began around 1845, when as a young man he took up an appointment with a Glasgow bank. As part of a group of like-minded associates, in 1851 Gray became a founder member of the Natural History Society of Glasgow, holding the positions of Treasurer and Secretary in turn (Gray, 1908). During the thirty or so years he resided in Glasgow, Gray made frequent visits to Loch Lomond, the completion in 1850 of an interconnected steamer and railway link between the City and Balloch having facilitated travel to the area still further. His first important contribution towards documenting the region's fauna was a text with annotated species lists of mammals, birds and fishes which was appended to a guide book to Loch Lomond and the Trossachs compiled by fellow Natural History Society member William Keddie (Keddie, 1864). Robert Gray's reputation as an ornithologist was further enhanced with the publication of his *Birds of the West of Scotland* (Gray, 1871) (Fig.1), Loch Lomondside being well represented in its carefully researched pages.

George Hector Leith Buchanan (1833-1903)

Sir George Hector Leith (his mother's name of Buchanan was not adopted until 1877) inherited his title before the age of nine. His interest in shooting and forming a collection of stuffed birds also began at an early age, soon attracting the attention of the zoological pundits of the day by obtaining Scotland's first example of Bonaparte's gull *Larus philadelpia* on Loch Lomondside in April 1850. However, like John Colquhoun before him, it was not until retiring from the army in 1859 and taking up residence at his mother's family seat at Ross Priory on the south shore of the loch that he was able to take up field sports in earnest. As a corresponding member of the Natural History Society of Glasgow, Sir George Leith Buchanan more than anyone was responsible for drawing attention to the ornithological richness of the wetlands in the lower flood plain of the River Endrick (Mitchell, 1985).

John Stirling (1832-1900) & Robert Kidston (1852-1924)

Two 19th century floras prepared by Glasgow botany professors which made mention of Loch Lomond and surrounds - *Flora Scotica* (1821) by William Hooker and the *Clydesdale Flora* (five editions between 1865 and 1891) by Roger Hennedy - were essentially compilations of casual records. A more systematic plant recording scheme covering Stirlingshire, which took in the eastern portion of Loch Lomondside, was initiated by Colonel John Stirling and Robert Kidston, both members of the Stirling Natural History and Archaeological Society (Anon, 1900; Edwards, 1984). With the aim of evenness in cover, the county was divided into recording areas based on the main geological formations, such as the red sandstone and metamorphic rock zones of the region. As the field work progressed, their flora was published in two main parts with eight supplements over a period of nine years in the *Transactions* of the Stirling Society (Stirling & Kidston, 1891 *et seq*).



THE

BIRDS OF THE WEST OF SCOTLAND

INCLUDING

THE OUTER HEBRIDES

WITH OCCASIONAL RECORDS OF THE OCCURRENCE OF THE RARER SPECIES THROUGHOUT SCOTLAND GENERALLY.

BY

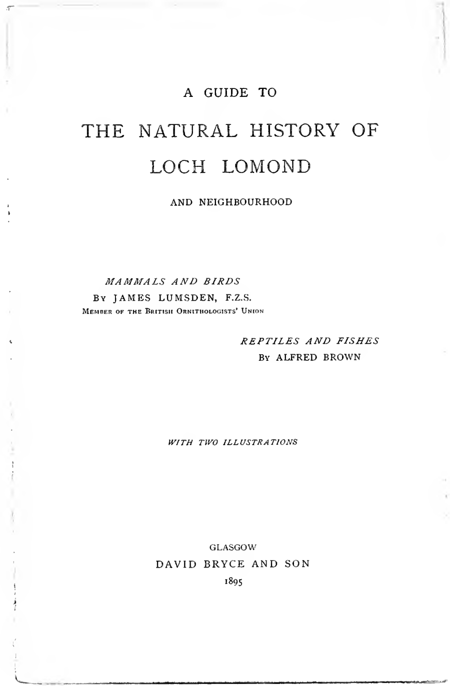
ROBERT GRAY

LATE SECRETARY TO THE NATURAL HISTORY SOCIETY OF GLASGOW;
MEMBER OF THE BRITISH ORNITHOLOGISTS' UNION;
CORRESPONDING MEMBER OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA;
AND OF THE DUMFRIESSHIRE AND GALLOWAY NATURAL HISTORY AND ANTIQUARIAN SOCIETY, ETC., ETC.

GLASGOW: THOMAS MURRAY & SON

MDCCCLXXI

Fig. 1. Gray's *Birds of the West of Scotland* (1871).



A GUIDE TO

THE NATURAL HISTORY OF

LOCH LOMOND

AND NEIGHBOURHOOD

MAMMALS AND BIRDS

BY JAMES LUMSDEN, F.Z.S.

MEMBER OF THE BRITISH ORNITHOLOGISTS' UNION

REPTILES AND FISHES

BY ALFRED BROWN

WITH TWO ILLUSTRATIONS

GLASGOW

DAVID BRYCE AND SON

1895

Fig. 2. Lumsden & Browns' *Natural History of Loch Lomond and Neighbourhood* (1895)

Francis Buchanan White (1842-1894)

A former student of Professor Balfour at Edinburgh University, Dr Francis Buchanan White was an outstanding all-round naturalist, playing a prominent role in establishing the Perthshire Society of Natural Science in 1867 and becoming the first Editor of the *Scottish Naturalist* in 1871 (Taylor, 1986). His major published work *The Flora of Perthshire* (Buchanan White, 1898) - which divided the county into districts by the principal watersheds - was unfortunately delayed until four years after the author's premature death. Dr. Buchanan White's 'Lomond District' in the *Flora* took in all of the River Falloch drainage area north of Inverarnan.

James Lumsden (1851-1911) & Alfred Brown (1840/1-1902)

Natural history recording on Loch Lomondside came of age with the publication of *A Guide to the Natural History of Loch Lomond and Neighbourhood* (Lumsden & Brown, 1895) (Fig.2), although, despite the all-embracing title, coverage was confined to the vertebrates of the area. The joint authors both enjoyed the advantage of living in the district and had previously written papers on Loch Lomondside's vertebrate fauna for scientific journals (Anon, 1902; Mitchell, 1998). In collaborating for the book, James Lumsden - a member of the Natural History Society of Glasgow - prepared the chapters on mammals and birds, while Alfred Brown - Secretary of the Loch Lomond Angling Association - took responsibility for reptiles, amphibians and fishes. Although much has been written on Loch Lomondside's wildlife since the late 19th century, Lumsden & Browns' *Guide* still holds a place amongst the standard works.

ACKNOWLEDGEMENTS

My special thanks to Allan Stirling and Dr. Jack Gibson for their valued comments on the draft paper, and to Norman Tait who kindly prepared the two figures for publication.

REFERENCES

Anon. (1900), Colonel John Stirling. Obituary: *Stirling Journal & Advertiser*, 25 May 1900.

Anon. (1902). Alfred Brown. Obituary: *Lennox Herald*, 31 May 1902.

Balfour, I.B., (1902). *Notes of* Botanical Excursions made by Professor John Hutton Balfour. *The Royal Botanic Garden, Edinburgh* 7,21-497.

Bettany, G.T. (1908). 'John Hutton Balfour (1808-1884)' in Dictionary of National Biography (2nd ed.), Vol.1, p.976. Smith & Elder, London.

Bowden, J.K. (1989). *John Lightfoot: His Work and Travels*. Royal Botanic Gardens, Kew.

Buchanan White, F. (1898). *The Flora of Perthshire*. Perthshire Society of Natural Science, Edinburgh.

Burns, J.H. (1993). David Ure (1749-1798): Breadth of Mind and Accuracy of Observation. *Glasgow Naturalist* 22, 259-275.

Colquhoun, J. (1878). *The Moor and the Loch* 2 vols. William Blackwood, Edinburgh.

Edwards, D. (1984). Robert Kidston: The Most Professional Palaeobotanist. *Forth Naturalist and Historian* 8,64-93.

Giles, Rev J.A. (1842). *The British History of Geoffrey of Monmouth*. James Bohn, London.

Gray, J.M. (1908). 'Robert Gray (1825-1887)' In *Dictionary of National Biography* (2nd ed.), Vol.VIII, pp.462-463. Smith & Elder, London.

Gray, R. (1871). *The Birds of the West of Scotland*. Thomas Murray, Glasgow.

Keddie, W. (1864). *Highland Route No.VII: Edinburgh and Glasgow to the Lake of Menteith, the Trossachs, Loch Katrine and Loch Lomond*. Maclure & Macdonald, Glasgow.

Lightfoot, Rev J. (1777). *Flora Scotica* 2 vols. B. White, London.

Lumsden, J. & Brown, A. (1895). *A Guide to the Natural History of Loch Lomond and Neighbourhood*. David Bryce, Glasgow.

Maitland, J.A.F. (1908). 'John Colquhoun (1805-1885)' in *Dictionary of National Biography* (2nd. ed.), Vol.IV, p.858. Smith & Elder, London.

Mitchell, Sir A. (1907). *MacFarlane's Geographical Collections relating to Scotland* Vol.II. Scottish History Society, Edinburgh.

Mitchell, J. (1985). 'Sir George Leith Buchanan' in Early Scottish Ornithologists on the Loch Lomondside Scene. *Loch Lomond Bird Report 1984* 13, 12-13.

Mitchell, J. (1986 & 1992). The Reverend John Stuart D.D. (1743-1821) and his contribution to the discovery of Britain's Mountain Flowers. *Glasgow Naturalist* 21, 119-125 & 22, 103-105.

Mitchell, J. (1998). James Lumsden: a late 19th century Bird Recorder. *Clyde Birds* 10, 144-145.

Stirling, J. & Kidston, R. (1891 *et seq)*. Notes on the Flora of the North-Western Portion of Stirlingshire. *Transactions of the Stirling Natural History and Archaeological Society* 13, 88-102.

Stuart, Rev J. (1796). 'Parish of Luss' in *The Statistical Account of Scotland* Vol.17, 238-271. William Creech, Edinburgh.

Taylor, M.A. (1986). Francis Buchanan White (1842-1894) and Scottish Botany. *Scottish Naturalist* 1986, pp. 157-173.

Ure, Rev D. (1794). *General View of the Agriculture in the County of Dumbarton*. W. Smith, London.

Ure, Rev D. (1795). 'Parish of Killearn' in *The Statistical Account of Scotland* Vol.16, 100-129. William Creech, Edinburgh.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 69-82.

ENVIRONMENTAL IMPACT ON THE SEA BED CAUSED BY TRAWLING FOR THE NORWAY LOBSTER, *NEPHROPS NORVEGICUS* IN THE CLYDE SEA AREA. A GEOTECHNICAL ASSESSMENT.

Azra Meadows, Peter S. Meadows and John M. H. Murray
Biosedimentology Unit, Division of Environmental and Evolutionary Biology Institute of Biomedical and Life Sciences, University of Glasgow, G12 8QQ, UK
Email: gbza21@udcf.gla.ac.uk. Web Site: www.gla.ac.uk/Acad/IBLS/Biosed

ABSTRACT

The Norway Lobster, *Nephrops norwegicus*, is a common benthic crustacean living on the sea bed in the Clyde Sea area, Irish Sea, North Sea, and Mediterranean. It lives between 50 metre and 400 metres water depth in fine mud and constructs large burrow systems. It is a high-value catch for local fishermen, and the most usual method of fishing is with an otter trawl. Otter trawls cause considerable disturbance to the sea bed. There have therefore been a number of investigations of the fishery, and on its environmental impact on the seabed and biological communities that live there.

Sediment cores were taken from high, medium and low trawl impact sites in the Clyde Estuary using a new sea-bed coring device developed at the University Marine Biological Station Millport (UMBS) by Dr P.R.O. Barnett. The new coring device provided sediment cores of c. 14 to 18 cm depth, that were undisturbed and were covered with in-situ overlying water. Two stations were selected at each of the three impact sites. The stations represented a range of sedimentary environments from sandy mud to fine mud. Sampling was conducted at four times during the 2000 - 2001 year: Spring 2000, Summer 2000, Autumn 2000, and Winter 2000/Spring 2001.

Immediately after collection, the sediment cores from the pairs of stations at the high, medium and low impact sites were submitted to six quantitive geotechnical tests in the laboratory. The geotechnical tests used were shear strength, load resistance, water content, dry bulk density and particle size mean and sorting. Measurements were taken at 0 - 2 cm, 4 - 6 cm, and 8 - 10 cm in the sediment cores.

Shear strength, load resistance and bulk density increased, and water content decreased, with increasing depth in the sedimentary column. There were no obvious changes in mean particle size or sorting with increasing depth in the sedimentary column. No marked seasonal changes were noted in any of the geotechnical parameters.

The six geotechnical parameters used all detected differences in the sediment structure and characteristics between the low, medium and high impact sites. There was a decrease in sediment shear strength, load resistance, dry bulk density, mean particle size, and particle size sorting, as trawling impact increased. There was an increase in sediment water content as trawling impact increased.

The degree to which the geotechnical parameters detected changes in sediment structure between the low, medium and high impact sites differed markedly. Shear strength and load resistance showed the largest differences and are therefore the most robust of the tests used. Shear strength decreased by 52% at the medium impact site and 87% at the high impact site, when compared with the low impact site. The equivalent changes for load resistance were a decrease of 47% and 86% respectively. The changes for bulk density were a decrease of 18% and 50%, and the changes for water content were an increase of 9% and 61%, at the medium and high impact sites respectively. The changes for phi mean particle size were an increase of 11% and 19%, and for phi sorting an increase of 3% and 5%.

In terms of the speed with which the geotechnical tests can be conducted, shear strength and load resistance are the fastest tests (4 hours), followed by water content and bulk density (7 days), and particle size mean and particle size sorting (14 days).

A Speed Robustness Index (SRI) has been developed for the six geotechnical parameters. This quantifies the effectiveness of the six parameters in terms of their percentage change as trawling intensity increases, and of the time taken to conduct the tests. Shear strength and load resistance have the highest SRI's of 17.4 and 16.6. Water content and bulk density have SRI's of 0.63 and 0.61, and mean particle size and sorting have SRI's of 0.18 and 0.05.

The results from this survey therefore show that shear strength and load resistance are the most effective of the six geotechnical parameters used to assess the environmental impact of Otter trawling on the structure of the sea bed in the Clyde Estuary. They are both rapid tests and both show large changes as trawling impact increases.

For the future, we suggest that the six geotechnical parameters used in this report are assessed in other high medium and low impact trawling areas of the sea bed in the Clyde Sea area and then further afield, to confirm their relative suitability and robustness in a wider range of environmental conditions. This should initially concentrate on areas where the Norway Lobster, *Nephrops norwegicus*, is abundant. It should then be extended to other commercially important species and to ecosystems where man's impact on the sea bed is thought to be deleterious.

INTRODUCTION

The Norway Lobster, *Nephrops norwegicus*, is a common benthic crustacean living on the sea bed in the Mediterranean, North Sea, and Irish Sea (Maynou et al. 1998; Relini, 1998; Sarda, 1998a, b; Abello et al. 2002). It is also found in considerable numbers off the west coast of Scotland, being well known from the Clyde Sea area and Firth of Clyde (Field et al. 1998; Tuck et al. 2000; Briggs & McAliskey, 2002; Parslow-Williams et al. 2002). The species lives subtidally, between about 50 metre and 400 metres water depth on fine muddy substrates where it constructs large burrow systems.

Nephrops norvegicus is a high-value catch for local fishermen, and the most usual method of fishing is with an otter trawl (Abella et al., 1999; Madsen & Nansen, 2001; Campos et al. 2002; Poulard & Leaute, 2002). These trawls and similar fishing gear are known to cause considerable disturbance to the sea bed during their operation (De Groot, 1984; Jones, 1992; Jennings & Kaiser 1998; Schwinghamer et al. 1998;Thrush et al. 1998), and there is some concern about the effects of this on the biodiversity of benthic communities (Hall et al. 1990; Kaiser et al. 1996; MacDonald et al. 1996; Hall & Harding, 1997; Engel & Kvitek 1998; Poiner et al. 1998; Ball, Fox, & Munday, 2000; Ball, Munday, & Tuck, 2000;Collie et al., 2000). There are also environmental effects caused by the discarded dead organisms from Nephrops trawlers (Stratoudakis et al. 2001; Bergman et al. 2002a, b). As a result, there have been a number of investigations of the fishery, and on its environmental impact on the seabed and biological communities that live there.

The objectives of our research was to find out whether simple physical measurements on sediments could identify the impact of otter trawl fishing for *Nephrops norwegicus* on the seabed in the Firth of Clyde which would then have application to other areas in which the species was abundant. This is particularly important in relation to benthic invertebrate communities living in the same environment as *Nephrops*. Many of the animals in these communities, including many molluscs, annelids, and echinoderms, are very sensitive to changes in the physical and chemical properties of the sediments on or in which they live (Meadows & Meadows, 1991). If these properties change, animals often cannot feed and burrow properly. They are therefore likely to die or move elsewhere. This reasoning has broader implications. The same sort of effects will be true of other marine environments in which anthropogenic disturbance takes place, such as the intertidal zone (Meadows & Tufail, 1986; Tufail, Meadows & McLaughlin, 1989; Meadows, Meadows & McLaughlin, 1998). This zone is often the site of digging for clams or edible cockles, and in some areas significant disturbance takes place by bathers and by research sampling. The problem has received little attention.

Specifically, we aimed to answer the question 'Can geotechnical parameters detect changes in the structure of the sea bed associated with an increase in Otter trawl activity?'. We therefore gave detailed consideration to the suite of tests that should be used. The tests should include standard as well as novel experimental protocols and equipment. They should provide a range of different geotechnical signatures for any change in sediment structure. The speed with which the results can be conducted should also receive detailed consideration.

The techniques that we used are part of a range of geotechnical measurements that are routinely used by civil engineers and environmentalists to quantify the properties of soils on land and sediments in freshwater and marine ecosystems (Meadows & Meadows, 1994). These are shear strength, load resistance, dry bulk density, water content, mean particle size and particle size sorting (standard deviation). These geotechnical techniques are all used routinely by the present authors and their co-workers (Meadows & Tufail, 1986; Meadows & Tait, 1985, 1989; Meadows & Meadows, 1994; Meadows et al. 2000, Murray et al. 2000), and have been tested over a number of years by us in a wide range of intertidal, continental shelf, continental slope and abyssal plain environments. Shear strength is known to quantify sediment structure in an engineering context, and load resistance is a novel microscale approach. Dry bulk density and water content are standard geotechnical parameters, and are likely to change with sediment disturbance. Mean particle size and sorting are routinely used by sedimentologists to distinguish between different sedimentary ecosystems, particularly in terms of different degrees of disturbance associated with high and low energy sea bed environments

MATERIALS AND METHODS

Stations, sampling dates and number of tests

High, medium and low trawling intensity sites, were identified in the Clyde Estuary by Dr R.J.A.Atkinson, and colleagues at the University Marine Biology Station Millport. Two stations were selected that were representative of each of the three sites, and were sampled during spring 2000, summer 2000, autumn 2000 and winter 2000/01 - a total of 24 stations in all. The pairs of stations at the high, medium and low trawling intensity sites, with their dates of sampling, latitude and longitude, and water depth, are given in table 1. Six geotechnical tests were conducted on cores from each station, hence in all 24 x 6 = 144 geotechnical tests were undertaken during the research.

Geotechnical Techniques

All the geotechnical techniques were conducted on cores of sediment that had been sampled from the sea bed within 24 hours. A new sea bed corer was used developed by Dr P.R.O. Barnett of UMBS. The sediment cores were contained in sealed

Table 1. Detailed log of the High, Medium and Low impact sites and their stations. Trawling Intensity sites, High (stations: WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area.

	Trawling Intensity					
	High		**Medium**		**Low**	
Spring 2000	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
Date	13.04.00	13.04.00	13.04.00	12.04.00	14.04.00	12.04.00
Lat. W	55° 41′ 29″	55° 35′ 21″	55° 44′ 40″	56° 01′ 30″	55° 47′ 25″	56° 03′ 27″
Long. N	04° 58′ 33″	05° 03′ 24″	05° 09′ 32″	04° 52′ 59″	04 56′ 19″	04° 53′ 19″
Water Depth (m)	81	97	81	61	37	86
Summer 2000						
Date	28.07.00	03.08.00	28.07.00	27.07.00	03.08.00	27.07.00
Lat. W	55° 41′ 51″	55° 35′ 22″	55° 45′ 24″	56° 01′ 55″	55° 47′ 32″	56° 03′ 56″
Long. N	04° 58′ 35″	05° 03′ 18″	05° 09′ 18″	04° 53′ 11″	04° 56′ 18″	04° 52′ 54″
Water Depth (m)	86	95	59	64	39	87
Autumn 2000						
Date	31.10.00	24.10.00	24.10.00	25.10.00	31.10.00	23.10.00
Lat. W	55° 41′ 30″	55° 35′ 46″	55° 45′ 36″	56° 01′ 18″	55° 47′ 31″	56° 03′ 36″
Long. N	04° 58′ 37″	05° 03′ 27″	05° 09′ 40″	04° 53′ 04″	04° 56′ 19″	04° 53′ 19″
Water Depth (m)	80	94	60	64	38	80
Winter 2000/1						
Date	22.02.01	26.02.01	26.02.01	23.02.01	22.02.01	23.02.01
Lat. W	55° 41′.22″	55° 35′ 44″	55° 45′ 19″	56° 01′ 39″	55° 47′ 36″	56° 03′ 50″
Long. N	04° 58′ 50″	05° 03′ 20″	05° 09′ 20″	04° 53′ 16″	04° 56′ 20″	04° 53′ 11″
Water Depth (m)	83	95	60	65	41	90

transparent core liners, internal diameter 85 cm height 30 cm. The sediment cores were 14 to 18 cm in height and were covered by in-situ overlying water. In the laboratory, the overlying water was siphoned off the sediment core. Shear strength was then measured on the surface of each sediment level, the sediment was then extruded and sliced, and sediment samples were taken from the sliced sections for water content, dry bulk density and particle size. Load resistance was measured on a separate core taken close to the first core on the sea bed. The overlying water on this second core was not siphoned off before load resistance was measured. Data for all the geotechnical parameters measured are presented for the following depths of the sedimentary column: 0 - 2 cm, 4 - 6 cm, and 8 - 10 cm. These three levels were chosen to represent the top, middle and bottom of the sediment core.

Shear Strength was measured using a Geonor Fall Cone apparatus (Meadows & Tait, 1985, 1989; Meadows & Meadows 1991; Meadows et al. 1994). It is expressed as kN/m^2 in the tables of results. Load resistance in kN was measured using a miniature load resistance penetrometer developed by Muir Wood et al. (1993), Meadows, P.S. et al. (1998) and Murray et al. (2000). The experimental protocols for measuring load resistance described in these three papers were followed with minor modifications. Water Content was measured by weighing wet sediment samples, and then drying at 80° C for 24 hours. This was followed by cooling in a dissector for 3 hours, after which the samples were weighed. Water content was then calculated as ((wet weight - dry weight)/dry weight)x100. It is presented as % water content in the tables of results (BS1377, 1975). Dry bulk density was measured on the same samples and was calculated as (volume of sediment)/ (dry weight of sediment). It is presented as g/ml in the tables of results. Particle size was measured as follows. Sediment from the three levels of the cores (0 - 2 cm, 4 - 6 cm, and 8 - 10 cm) was supplied to the Marine Laboratory Aberdeen for granulometric analysis. The Marine Laboratory Aberdeen provided granulometric data as percentages at half phi intervals from 1 to 11. This data was then used by the authors to calculate the phi mean and phi sorting of each sample (Buchanan, 1984). The data are presented as phi mean and phi sorting in the tables of results, where phi = -($\log_2$ particle diameter in mm). Hence -1 phi = 2 mm, 0 phi = 1 mm, +1 phi = 500 micron, +2 phi = 250 micron, +3 phi = 125 micron and so on.

RESULTS

The results of each of the geotechnical parameters measured are presented in the same tabular format. There is one table for each parameter: each presents the data for spring 2000, summer 2000, autumn 2000 and winter 2000/spring 2001. In each table data are presented for 0 - 2 cm, 4 - 6 cm, and 8 - 10 cm sediment depths. These are presented for the two high impact stations (Wee Cumbrae and Brodick), the two medium impact stations (Inchmarnock and Lower Loch Long) and the two low impact stations (Hush Hush and Mid Loch Long) .

Sediment Shear Strength and Load Resistance

Sediment shear strength and load resistance data are presented in tables 2 and 3. An inspection of these eight tables show a number of common features.

Shear strength and penetration resistance are closely related. Low shear strength occurs in a sediment having a low load resistance, and high shear strength occurs in sediment having a high load resistance. This is to be expected from previous work by the authors (Meadows, P.S. et al. 1998; Murray et al. 2000) and indicates that the two techniques are measuring similar properties of the sedimentary column. Both shear strength and load resistance increase slightly with increasing sediment depth. This is a common feature of such data (Meadows & Tait, 1985; Meadows & Tufail, 1986; Meadows & Meadows, 1991; Meadows, P.S. et al. 1998; Meadows, A. et al., 2000; Murray et al., 2000).

There is very little difference in the two parameters between the four seasons. In other words there is no marked seasonal signature in the results. There is some suggestion in the data that there is a decrease in shear strength and a decrease in load resistance as trawling impact increases, however there is considerable variation. This effect is considered in more detail below (section 5)

Water Content and Dry Bulk Density

The data for water content and dry bulk density are presented in table 4 and 5. It is clear from the data in these two tables that water content and dry bulk density are inversely related. When water content is high, dry bulk density is low, and when water content is low dry bulk density is high. This is as expected. When a sediment contains less water the individual particles are more tightly packed together which in turn produces a higher bulk density.

There is a decrease in water content and increase in dry bulk density with increasing sediment depth at all the stations. This effect is well known. There is very little difference in the two parameters between the four seasons. There is hence no seasonal signature shown by either parameter. There is some indication from the data that water content increases and bulk density decreases as trawling impact increases, however there is considerable variation. This effect is considered in more detail below (section 5).

Particle Size. Mean and Sorting

The data for mean particle size and sorting (standard deviation) are presented in table 6 and 7. The units used are phi units, following standard sedimentological procedure (cf. Buchanan, 1984). In these units a higher value of mean phi represents a smaller particle size, and a lower value for mean phi represents a larger particle size. This is not so of the phi sorting (phi standard deviation). Here a

higher phi standard deviation (defined as a lower sorting) indicates a wider scatter of data, and a lower phi standard deviation (defined as a higher sorting) indicates a smaller scatter of data - just as in normal standard deviations.

Table 2. Sediment shear strength (kN. m^{-2}) mean ± s.d. values (n = 6) at top (0-2 cm), mid (4-6 cm) and bottom (8-10 cm) depths down a sediment core (core internal diameter = 10 cm). Three Trawling Intensity sites, High (stations :WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area. First set of data: Spring 2000; second set: Summer 2002; third set: Autumn 2000; fourth set winter 2001.

	Trawling Intensity					
	High		**Medium**		**Low**	
Sediment Depth	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
0-2 cm	0.137 ± 0.062	0.102 ±0.043	0.149 ±0.072	0.502 ±0.064	1.396 ±0.412	0.150 ±0.028
4-6 cm	0.423 ±0.094	0.373 ±0.150	1.140 ±0.625	0.573 ±0.066	2.704 ±0.964	0.354 ±0.072
8-10 cm	0.345 ±0.132	0.511 ±0.205	2.439 ±0.604	0.505 ±0.094	10.103 ±4.736	0.422 ±0.127
0-2 cm	0.107 ± 0.027	0.118 ±0.049	0.255 ±0.137	0.122 ±0.045	0.666 ±0.457	0.118 ±0.028
4-6 cm	0.616 ±0.264	0.432 ±0.153	1.619 ±0.334	0.507 ±0.100	8.240 ±5.780	0.492 ±0.113
8-10 cm	2.370 ±1.706	0.552 ±0.097	5.299 ±2.594	0.816 ±0.298	14.157 ±11.329	0.816 ±0.171
0-2 cm	0.129 ±0.053	0.096 ±0.026	0.250 ±0.161	0.150 ±0.085	0.788 ±0.553	0.139 ±0.039
4-6 cm	0.384 ±0.127	0.522 ±0.170	4.974 ±2.849	0.412 ±0.114	5.837 ±1.426	0.352 ±0.007
8-10 cm	0.889 ±0.224	0.531 ±0.072	1.345 ±1.428	0.781 ±0.297	7.237 ±2.642	0.799 ±0.158
0-2 cm	0.151 ±0.070	0.090 ±0.030	0.487 ±0.242	0.114 ±0.040	0.968 ±0.918	0.135 ±0.071
4-6 cm	0.589 ±0.140	0.463 ±0.075	3.134 ±1.761	0.549 ±0.164	6.680 ±5.220	0.401 ±0.084
8-10 cm	0.866 ±0.223	0.730 ±0.132	15.210 ±7.47	0.847 ±0.154	22.84 ±12.81	1.142 ±0.293

Table 3. Load resistance (kN) mean ± s.d. values (n = 26) at top (0-2 cm), mid (4-6 cm) and bottom (8-10 cm) depths down a sediment core (core internal diameter = 10 cm). A 30 mm diameter penetration probe was used. Three Trawling Intensity sites, High (stations :WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area. OS: load resistance over scale, value of greater than 100 N. First set of data: Spring 2000; second set: Summer 2002; third set: Autumn 2000; fourth set winter 2001.

	Trawling Intensity					
	High		Medium		Low	
Sediment Depth	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
0-2 cm	0.072 ±0.079	0.370 ±0.218	0.959 ±0.615	0.784 ±0.459	6.532 ±5.467	0.861 ±0.637
4-6 cm	1.564 ±0.305	2.464 ±0.590	6.208 ±1.114	4.960 ±0.630	55.91 ±12.50	4.198 ±0.409
8-10 cm	4.254 ±0.505	10.04 ±1.547	13.02 ±0.443	14.77 ±2.144	66.71 ±1.261	6.735 ±0.356
0-2 cm	0.323 ±0.275	0.456 ±0.299	3.194 ±2.386	0.854 ±0.688	7.498 ±6.006	0.324 ±0.22 8
4-6 cm	3.432 ±0.574	3.050 ±0.310	38.57 ±6.663	6.329 ±0.834	85.19 ±11.97	3.234 ±0.658
8-10 cm	5.784 ±0.230	5.998 ±0.530	85.62 ±7.825	10.38 ±0.531	OS	7.652 ±0.499
0-2 cm	0.695 ±0.507	0.646 ±0.424	1.064 ±0.611	1.076 ±0.642	4.100 ±2.528	0.563 ±0.385
4-6 cm	6.000 ±0.698	4.429 ±0.748	8.010 ±1.931	5.910 ±0.740	44.54 ±11.89	3.398 ±0.401
8-10 cm	10.95 ±0.975	9.694 ±0.744	24.02 ±2.332	8.842 ±0.239	OS	6.582 ±0.630
0-2 cm	0.858 ±0.498	0.306 ±0.232	4.040 ±3.266	0.652 ±0.392	4.455 ±3.913	0.890 ±0.514
4-6 cm	4.810 ±0.561	2.382 ±0.427	31.90 ±4.940	3.039 ±0.433	47.54 ±10.88	4.116 ±0.470
8-10 cm	8.032 ±0.473	4.752 ±0.253	72.96 ±6.932	6.629 ±0.740	OS	8.672 ±1.039

Table 4. Water content (%) mean ± s.d. values (n = 4) at top (0-2 cm), mid (4-6 cm) and bottom (8-10 cm) depths down a sediment core (core internal diameter = 10 cm). The three Trawling Intensity sites, High (stations :WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area. First set of data: Spring 2000; second set: Summer 2002; third set: Autumn 2000; fourth set: winter 2001.

	Trawling Intensity					
	High		Medium		Low	
Sediment Depth	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
0-2 cm	208.45 ±16.022	252.75 ±25.189	116.70 ±21.765	205.53 ±11.022	40.87 ±4.279	232.05 ±4.208
4-6 cm	167.10 ±1.977	196.10 ±8.163	78.15 ±2.765	209.73 ±90.854	36.095 ±2.551	196.53 ±5.525
8-10 cm	163.35 ±9.840	185.55 ±5.444	73.33 ±2.210	158.425 ±8.019	29.325 ±0.807	177.85 ±11.388
0-2 cm	240.83 ±45.723	224.65 ±9.110	79.73 ±16.596	229.60 ±11.257	43.70 ±4.975	255.68 ±26.109
4-6 cm	149.70 ±4.491	194.33 ±3.732	47.70 ±0.970	170.33 ±4.371	31.60 ±1.052	183.13 ±6.562
8-10 cm	121.83 ±5.090	178.88 ±4.001	53.05 ±2.330	142.65 ±2.483	27.23 ±0.967	167.08 ±7.475
0-2 cm	217.70 ±22.241	254.48 ±12.891	110.05 ±15.765	233.45 ±25.501	40.25 ±4.234	246.73 ±6.620
4-6 cm	172.65 ±14.214	187.93 ±5.902	67.33 ±3.784	178.80 ±6.351	30.95 ±0.790	201.65 ±4.966
8-10 cm	142.95 ±0.889	177.68 ±3.745	68.50 ±1.874	152.95 ±4.088	30.05 ±0.778	174.03 ±1.752
0-2 cm	214.06 ±12.57	253.50 ±16.82	54.01 ±6.93	243.20 ±23.20	36.93 ±3.360	255.50 ±38.00
4-6 cm	154.23 ±6.61	197.34 ±8.07	39.75 ±1.55	179.57 ±4.81	29.11 ±4.62	191.35 ±4.59
8-10 cm	140.82 ±3.11	167.54 ±4.41	40.69 ±1.80	157.25 ±3.38	27.10 ±0.319	158.02 ±2.02

Table 5. Dry bulk density (g.ml^{-1}) mean ± s.d. values (n = 4) at top (0-2 cm), mid (4-6 cm) and bottom (8-10 cm) depths down a sediment core (core internal diameter = 10 cm). Three Trawling Intensity sites, High (stations :WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area.. First set of data: Spring 2000; second set: Summer 2002; third set: Autumn 2000; fourth set winter 2001.

	Trawling Intensity					
	High		**Medium**		**Low**	
Sediment Depth	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
0-2 cm	0.713 ±0.050	0.600 ±0.052	1.146 ±0.164	0.714 ±0.021	2.281 ±0.105	0.668 ±0.008
4-6 cm	0.865 ±0.025	0.769 ±0.017	2.097 ±0.040	0.773 ±0.167	2.388 ±0.092	0.773 ±0.013
8-10 cm	0.874 ±0.041	0.799 ±0.022	2.162 ±0.038	1.197 ±0.333	2.620 ±0.049	0.821 ±0.053
0-2 cm	0.654 ±0.090	0.676 ±0.021	1.518 ±0.207	0.654 ±0.032	2.183 ±0.138	0.591 ±0.041
4-6 cm	0.956 ±0.026	0.763 ±0.012	2.091 ±0.022	0.847 ±0.011	2.545 ±0.026	0.801 ±0.030
8-10 cm	1.124 ±0.031	0.817 ±0.020	1.998 ±0.061	0.979 ±0.011	2.703 ±0.064	0.862 ±0.038
0-2 cm	0.689 ±0.062	0.581 ±0.021	1.240 ±0.182	0.656 ±0.069	2.060 ±0.457	0.616 ±0.018
4-6 cm	0.840 ±0.067	0.794 ±0.021	1.745 ±0.073	0.828 ±0.022	2.624 ±0.038	0.744 ±0.015
8-10 cm	0.980 ±0.011	0.841 ±0.015	1.680 ±0.028	0.925 ±0.021	2.679 ±0.023	0.848 ±0.014
0-2 cm	0.398 ±0.018	0.342 ±0.022	1.100 ±0.0926	0.355 ±0.0307	1.351 ±0.069	0.338 ±0.051
4-6 cm	0.536 ±0.016	0.428 ±0.017	1.323 ±0.0340	0.467 ±0.012	1.532 ±0.064	0.448 ±0.014
8-10 cm	0.578 ±0.009	0.497 ±0.008	1.308 ±0.027	0.527 ±0.007	1.610 ±0.020	0.519 ±0.008

Table 6. Particle Size. Phi mean ± s.d. values (n = 4) at top (0-2 cm), mid (4-6 cm) and bottom (8-10 cm) depths down a sediment core (core internal diameter = 10 cm). Three Trawling Intensity sites, High (stations :WCUM Wee Cumbrae, BROD Brodick), Medium (stations : INCH Inchmarnock, LOLL Lower Loch Long) and Low (stations : HUHU Hush Hush, MLL Mid Loch Long) in the Clyde Sea area.. First set of data: Spring 2000; second set: Summer 2002; third set: Autumn 2000; fourth set winter 2001.

	Trawling Intensity					
	High		Medium		Low	
Sediment Depth	**WCUM**	**BROD**	**INCH**	**LOLL**	**HUHU**	**MLL**
0-2 cm	5.810 ±1.861	6.595 ±1.356	5.271 ±1.882	5.496 ±1.848	4.280 ±2.024	6.009 ±1.656
4-6 cm	4.771 ±2.784	6.244 ±2.195	5.412 ±2.011	5.712 ±1.978	4.272 ±2.039	6.100 ±1.471
8-10 cm	3.120 ±2.879	5.314 ±2.900	5.544 ±1.836	5.773 ±2.055	4.287 ±1.971	6.159 ±1.500
0-2 cm	5.849 ±1.754	6.266 ±1.545	4.828 ±2.018	6.157 ±1.412	3.920 ±1.975	6.073 ±1.476
4-6 cm	5.995 ±1.681	6.214 ±1.959	4.961 ±2.000	6.029 ±1.540	4.127 ±1.954	6.214 ±1.523
8-10 cm	5.924 ±1.680	6.238 ±1.820	5.407 ±2.256	6.011 ±1.619	3.988 ±2.014	6.096 ±1.496
0-2 cm	5.946 ±1.770	5.942 ±1.985	5.461 ±1.687	5.758 ±1.656	3.845 ±1.928	5.907 ±1.580
4-6 cm	6.052 ±1.687	6.330 ±1.554	5.724 ±1.658	5.924 ±1.558	3.978 ±1.966	5.725 ±1.726
8-10 cm	6.096 ±1.691	6.302 ±1.700	5.894 ±1.672	6.056 ±1.457	4.304 ±1.909	5.912 ±1.756
0-2 cm	6.335 ±1.601	6.523 ±1.425	4.619 ±2.073	6.177 ±1.523	3.938 ±2.018	6.224 ±1.353
4-6 cm	6.390 ±1.412	6.606 ±1.424	4.608 ±2.142	6.080 ±1.545	3.740 ±1.466	6.220 ±1.407
8-10 cm	6.448 ±1.519	6.632 ±1.522	5.010 ±2.202	6.337 ±1.403	3.837 ±1.943	6.254 ±1.592

In contrast to the previously described parameters, there is no consistent increase or decrease in the particle size mean or sorting as sediment depth increases. However in common with the previously described parameters there is very little difference between the four seasons.

There is some indication from the data that as trawling impact increases, the mean particle size decreases (increase in phi mean particle size), and the particle sorting decreases (increase in phi particle size standard deviation). This effect is considered in more detail below (section 5).

CONCLUSIONS

Increased Trawling Impact and Changes in the Measured Geotechnical Parameters

Careful consideration has been given to the way in which the effects of increasing trawling for *Nephrops norvegicus* and its impact on the measured geotechnical parameters could be quantified. It was eventually decided to calculate the means and standard deviations for each parameter in turn for the high impact stations, for the medium impact stations, and for the low impact stations. This was done using the data for all three sediment depths, all four seasons, and the two stations at each impact level. This resulted in a series of means and standard deviations based on individual means from three sediment depths, two stations, four seasons. Each mean and standard deviation is therefore base on 3 x 2 x 4 = 24 readings. The results are given in table 7.

Statistically, care needs to be exercised in calculating means of means, and in basing deductions on them. However the data in table 7 suggest that increasing trawl impact does have effects on all the geotechnical parameters measured. These effects are as follows. Sediment shear strength and sediment load resistance decrease with increasing trawl impact. Sediment water content increases with increasing trawl impact. Dry bulk density decreases with increasing trawl impact. Sediment mean particle size decreases (increasing phi mean) with increasing trawl impact. Sediment sorting decreases (increasing phi standard deviation) with increasing trawl impact.

The results in table 7 therefore indicate that any one of the six sedimentary geotechnical parameters measured can detect differences caused by trawl impact on the sediment fabric within the top 10 cm of the sedimentary column.

An Interpretation of the Observed Effects

If one assumes that Otter trawling for *Nephrops norvegicus* will disturb the sediment fabric to a depth well in excess of the 10 cm sediment cores investigated in the present study, a mechanism for the observed changes in the sedimentary geotechnical parameters can be suggested.

Trawling over and through the surficial layers of a sediment will both mix the sediment and disperse it vertically and horizontally. This will immediately lead to a lower shear strength, load resistance and bulk density, and to a higher water content. It will also lead to a reduction in sorting (increased standard deviation of particle size). It is not so obvious however, why trawling should lead to a reduction in mean particle size - as observed in the present study. Perhaps finer material is released from deeper parts of the sedimentary column by the effect of the trawling. Alternatively, the finer material is captured in some way from the overlying water column by persistent trawling, and then incorporated into the surficial layers of the sedimentary column. Physico-chemical flocculation processes and biological activity of one form or another may play a role in both of these hypothesised processes.

Speed and Robustness of the Six Sedimentary Parameters as Indicators of Trawling Intensity and Sediment Disturbence on Nephrops grounds

Our aim was to assess and develop a rapid methodology for quantifying environmental impacts of Otter trawls on the sea bed. Consideration has therefore been given to assessing the speed of the geotechnical techniques used above and to their robustness.

A quantitative assessment has been made of the time required to conduct each of the six techniques, and to collate and calculate the results from each. This has led to the conclusion that shear strength and load resistance are the quickest, followed by water content, bulk density, particle size mean and particle size sorting in that order - particle size mean and sorting being the slowest. Our assessments indicate that final results for shear strength and load resistance can be available in table form on disc, within about four hours of receiving the sediment cores in the laboratory. This contrasts with a period of about seven days for water content and bulk density, and about fourteen days for particle size mean and sorting. These times are based on one person conducting each of the tests, using the methodology and experimental protocols adopted in the present work.

Robustness is here defined as the ability of a given geotechnical test to detect differences in sediment structure between high, medium and low trawling impact sites. In order to assess this, the data in table 7 were expressed as percentage changes in relation to the low impact site data for each of the geotechnical parameters. These percentages are given in table 8. They show clearly that shear strength and load resistance are the most robust of the tests used, and particle size mean and sorting are the least robust, in terms of percentage change from the low impact site value. For example, shear strength decreased by 52% at the medium impact site and 87% at the high impact site, when compared with the mean value at the low impact site. The equivalent changes for load resistance were a decrease of 47% and 86% respectively. The changes for bulk density were a decrease of 18% and 50%, and the changes for water content were an increase of 9% and 61%, at the medium and high impact sites respectively. The changes for phi mean particle size were an increase of 11% and 19%, and for phi sorting an increase of 3% and 5%. The ranked order based on the percentage changes at the medium and high impact sites when compared with the low impact site (table 8) is hence shear strength and load resistance (most robust), water content and dry bulk density, mean particle size, and particle size sorting (least robust).

Table 7. Summary table of trawling impact is assessed by changes in sedimentary parameters.
Dry bulk density (g/ml), particle size (phi) mean and sorting, shear strength (kN/m2), load resistance (kN), water content (%).
Each mean and standard deviation is based on 24 values (two sites, four seasons : spring, summer, autumn, winter, and three sediment depths: top, middle and bottom).

Trawling Impact	DRY BULK DENSITY	PARTICLE SIZE		SHEAR STRENGTH	LOAD RESISTANCE	WATER CONTENT
		MEAN	SORTING			
High	0.7204 ±0.1948	5.998 ±0.7416	1.821 ±0.4457	0.4713 ±0.4793	3.797 ±3.360	190.2 ±37.34
Medium	1.179 ±0.5461	5.594 ±0.5006	1.793 ±0.2634	1.755 ±3.198	14.74 ±22.24	128.8 ±67.69
Low	1.438 ±0.8611	5.059 ±1.053	1.739 ±0.2405	3.624 ±5.604	27.91 ±36.60	118.4 ±90.19

Table 8. Summary table of trawling impact as assessed by changes in sedimentary parameters.
Dry bulk density, particle size mean and sorting, shear strength, load resistance, water content. Percentages calculated as follows: means in table 22 are expressed as percentage increases or decreases from the low trawling impact means (100%). SRI = Speed Robustness Index.

Trawling Impact	DRY BULK DENSITY	PARTICLE SIZE		SHEAR STRENGTH	LOAD RESISTANCE	WATER CONTENT
		MEAN	SORTING			
High	-50%	+19%	+5%	-87%	-86%	+61%
Medium	-18%	+11%	+3%	-52%	-47%	+9%
Low	100%	100%	100%	100%	100%	100%
SRI	0.61	0.18	0.05	17.4	16.6	0.63

An Index of Speed and Robustness of the Geotechnical Parameters

We have combined the assessments of speed and robustness of each of the techniques in a Speed Robustness Index (SRI) for each technique. The SRI is defined as follows:

$SRI = |a + b| / 2c$

where:

a = % increase or decrease in the observed parameter at the high impact site compared with the low impact site. b = % increase or decrease in the observed parameter at the medium impact site compared with the low impact site. c = hours taken to conduct the test, and to collate and present the data in hard copy and on disc, based on an eight hour working day.

Application of the SRI to the percentages in table 8 and using the times taken to conduct the tests provides a quantitative assessment of the overall efficiency of the six tests used in terms of their speed and robustness. The SRI values are given at the bottom of table 8. Using the SRI it is clear that shear strength and load resistance are the best tests, and particle size and sorting are the worst tests, for the assessment of the impact of trawling for *Neprhops norvegicus* on sea bad structure in the Clyde Estuary. Shear strength and load resistance have the highest SRI's of 17.4 and 16.6. Water content and bulk density have SRI's of 0.63 and 0.61, and mean particle size and sorting have SRI's of 0.18 and 0.05.

FUTURE WORK

The geotechnical parameters used in the current investigation have demonstrated that differences in seabed structure attributable to Otter trawl impact can be detected by relatively simple and rapid technology. However the local characteristics of the sea bed in the area sampled may not be fully representative of the environments in which Otter trawling is used on continental shelves elsewhere.

For the future, therefore, we suggest that the six geotechnical parameters used in this report are assessed in other high, medium and low impact trawling areas of the sea bed, to confirm their relative suitability and robustness in a wider range of environmental conditions. We recommend that the new corer designed by Dr Barnett should be developed to take four cores of a longer length. We strongly recommend that the load resistance equipment used in the current investigation is modified to quantify additional geotechnical parameters, and then developed for laboratory operation and for in situ operation on the sea bed with automatic data logging facilities in real time.

In a broader context, it would now be interesting to use the same group of geotechnical tests to assess sea bed disturbance in other areas, which could be linked to changes in benthic community structure and function caused by anthropogenic and natural sea bed disturbance. In a sense, this has already begun, as we have conducted similar work over a number of years in the Pacific and Atlantic, and also in the Arabian Sea These studies show clearly how geotechnical and geochemical parameters of the sea bed are related to the number and species of benthic organisms, benthic community structure and function, and more generally to the biodiversity of intertidal, near shore, and deep sea environments.

ACKNOWLEDGEMENTS

We thank Jim Atkinson and Geof Moore, University Marine Biology Station Millport, for inviting us to take part in the EC project. We thank Rupert Ormond, Director of UMBS, who has been very supportive and helped us in a number of ways. We thank Peter Barnett and Roger Coggans for helping to take the field samples, and Peter Barnett for the use of his new seabed corer. We are particularly grateful to the skippers, Mick Parker and Duncan Fraser, and to the crews of R.V. Aora and R.V. Aplysia, and to the ancillary staff at UMBS, all of whom were extremely helpful during this work..

REFERENCES

Abella, A., Belluscio, A., Bertrand, J., Carbonara, P.L., Giordano, D., Sbrana, M., & Zamboni, A. Use of MEDITS trawl survey data and commercial fleet information for the assessment of some Mediterranean demersal resources. *Aquatic Living Resources*, 12, 155-166.

Abello, P., Abella, A., Adamidou, A., Jugic-Peladic, S. Maiorano, P., & Spedicato M.T. 2002. Geographical patterns in abundance and population structure of Nephrops norvegicus and Parapenaeus longirostris (Crustacea: Decapoda) along the European Mediterranean coasts. Scientia Marina, 66, 125-141.

Bergmann, M., Wieczorek, Moore, P.G. & Atkinson, R.J.A. 2002a. Discard composition of the Nephrops fishery in the Clyde Sea area, Scotland. *Fisheries Research*, 57, 169-183.

Bergmann, M., Wieczorek, Moore, P.G. & Atkinson, R.J.A. 2002b. Utilisation of invertebrates discarded from the Nephrops fishery by various selective invertebrate scavengers in the west of Scotland. *Marine Ecology Progress Series*, 233: 185-198.

Ball, B.J., Fox, G., and Munday, B.W. 2000. Long and short-term consequences of a Nephrops trawl fishery on the benthos and environment of the Irish Sea. *ICES Journal of Marine Science*, 57, 1315-1320.

Ball, B.J, Munday, B.W. & Tuck, I. 2000. Effects of otter trawling on the benthos and environment in muddy sediments. Chapter 5, pp 69-82 in Kaiser, M.J. & de Groot, S.J. (Edit.) *The Effects of Fishing on Non-target Species and Habitats*. Blackwell Science, Oxford.

Buchanan, 1984. Sediment analysis. Ch.3, pp 41-65 in *Methods for the Study of Marine Benthos*. Ed. Holme, N.A. & McIntyre, A.D. 2nd Edition. Blackwell Scientific, Oxford.

BS 1377 1975. *Methods of Test for Soils for Civil Engineering Purposes*. Third revision. British Standards Institution, London.

Campos, A., Fonseca, P. & Erzini, K. 2002. Size selectivity of diamond and square mesh cod ends for rose shrimp (Parapenaeus longirostris) and Norway lobster (Nephrops norvegicus) off the Portuguese south coast. *Fisheries Research*, 58, 281-301.

Collie, J.S., Hall, S.J., Kaiser, M.J., and Poiner, I.R. 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology*, 69, 785-798.

Engel, J., and Kvitek, R. 1998. Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. *Conservation Biology*, 12, 1204-1214.

Field, R.H., Hills, J.M., Atkinson, R.J.A., Magill, S., & Shanks, A.M. 1998. Distribution and seasonal prevalence of Hematodinium sp. Infection of the Norway lobster (Nephrops norvegicus) around the west of Scotland. *ICES Journal of Marine Science*, 55, 845-858.

De Groot, S.J. 1984. The impact of bottom trawling on benthic fauna of the North Sea. *Ocean Management*, 9, 177-190.

Hall, S.J. & Harding, M.J.C. 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. *Journal of Applied Ecology*, 34, 497-517.

Hall, S.J., Basford, D.J., & Robertson, M.R. 1990. The impact of hydraulic dredging for Razor clams *Ensis* sp. on an infaunal community. *Netherlands Journal of Sea Research*, 27, 119-125.

Jennings, S. and Kaiser, M. J. 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology,* 34, 201-340.

Jones, J.S. 1992. Environmental impact of trawling on the seabed. *New Zealand Journal of Marine and Freshwater Research*, 26, 59-67.

Kaiser, M.J., Hill, A.S., Ramsay, K., Spencer, B.E., Brand, A.R. Veale, L.O., Prudden, K., Rees, E.I.S., Munday, B.W., Ball, B., & Hawkins, S.J. 1996. Benthic disturbance by fishing gear in the Irish Sea: a comparison of beam trawling and scallop dredging. *Aquatic Conservation, Marine and Freshwater Ecosystems*, 6, 269-285.

MacDonald, D.S., Little, M. Eno, N.C. & Hiscock, K. 1996. Disturbance of benthic species by fishing activities: a sensitivity index. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 6, 257-268.

Madsen, N. & Hansen, K.E. 2001. Danish experiments with a grid system tested in the North Sea shrimp fishery. *Fisheries Research*, 52, 203-216.

Maynou, F.X., Sarda, F. & Conan, G.Y. 1998. Assessment of the spatial structure and biomass evaluation of Nephrops norvegicus (L.) populations in the northwestern Mediterannean by geostatistics. *ICES Journal of Marine Science*, 55, 102-120.

Meadows, P.S. & Meadows, A. I991. The geotechnical and geochemical implications of bioturbation in marine sedimentary ecosystems. In *The Environmental Impact of Burrowing Animals and Animal Burrows*. Meadows, P.S. & Meadows, A. (Eds.). Symp. Zool. Soc. Lond., 63: 157-181.

Meadows, P.S. & Meadows, A. 1994. Bioturbation in deep sea Pacific sediments. *Journal of the Geological Society*, 151:361-375.

Meadows, P.S. & Tait, J. 1985. Bioturbation, geotechnics and microbiology at the sediment-water interface in deep sea sediments. pp 191-199 in *19th European Marine Biology Symposium*. edit P.E. Gibbs. Cambridge University Press: Cambridge.

Meadows, P.S. & Tait, J. 1989. Modification of sediment permeability and shear strength by two burrowing invertebrates. *Marine Biology*. 101: 75-82.

Meadows, A., Meadows, P.S., & McLaughlin, P. 1998. Spatial heterogeneity in an intertidal sedimentary environment and its macrobenthic community. In: Black, K.S., Paterson, D.M. & Cramp, A. (eds) *Sedimentary Processes in the Intertidal Zone, Geological Society, London, Special Publications* 139, 367-388.

Meadows, P.S., Murray, J.M.H., Meadows, A. Muir Wood, D., & West, J.F.C. 1998. Microscale biogeotechnical differences in intertidal ecosystems. In: Black, K.S., Paterson, D.M. & Cramp, A. (eds) *Sedimentary Processes in the Intertidal Zone, Geological Society, London, Special Publications* 139, 349-366.

Meadows, P.S., Reichelt, A.C., Meadows, A., & Waterworth, J.S. 1994. Microbial and meiofaunal abundance, redox potential and shear strength profiles in deep sea Pacific sediments. *Journal of the Geological Society*, 151: 377-390.

Meadows, A., Meadows, P.S., West, J.F.C, & Murray, J.M.H. 2000. Bioturbation, geochemistry and geotechnics of sediments affected by the oxygen minimum zone on the Oman continental slope and abyssal plain, Arabian Sea. *Deep-Sea Research. II*, 47: 259-280.

Meadows, P.S. & Tufail, A. 1986. Bioturbation, microbial activity and sediment properties in an estuarine ecosystem. *Proc. R. Soc. Edinb. B*: 90: 129-142.

Muir Wood, D., Meadows, P.S., Meadows, A., & Murray, J.M.H. 1993. Biological strengthening of marine sediments. Final Report SERC GR / G2446, MTD FOU 29: 1 - 48.

Murray, J.M.H., Meadows, A., Meadows, P.S., West, F.C.W. & Muir Wood, D. 2000. Microscale geotechnical variability in continental shelf and abyssal sediments influenced by the oxygen minimum zone in the Arabian Sea. *Deep-Sea Research*. II, 47: 281-301.

Parslow-Williams, P., Goodheir, C., Atkinson, R.J.A., & Taylor, A.C. 2002. Feeding energetics of the Norway Lobster Nephrops norvegicus in the Firth of Clyde, Scotland. *Ophelia*, 56, 101-120.

Poiner, I., Glaister, J., Pitcher, R., Burridge, C., Wassenberg, T., Gribble, N., Hill, B., Blaber, D., Milton, D., Brewer, D., & Ellis, N. 1998. *The environmental effects of prawn trawling in the far northern section of the great barrier reef marine park*: 1991-1996. Final report to Great Barrier Reef Marine Park Authority and Fisheries Research and Development Corporation. S1-25, & 1-5.

Poulard, J.C. & Leaute, J.P. 2002. Interaction between marine populations and fishing activities: temporal patterns of landings of La Rochelle trawlers in the Bay of Biscay. *Aquatic Living Resources*, 15, 197-210.

Relini, L.O., Zamboni, A., Fiorentino, F. & Massi, D. 1998. Reproductive patterns in Norway lobster Nephrops norvegicus (L.) (Crustacea, Decapoda , Nephropidae) of different Mediterranean areas. *Scientia Marina*, 62, 24-41.

Sarda, F. 1998a. Nephrops norvegicus (L): Comparative biology and fishery in the Mediterranean Sea. Introduction, conclusions and recommendations. *Scientia Marina*, 62, 5-15.

Sarda, F. 1998b. Symptoms of overexploitation in the stock of the Norway lobster (Nephrops norvegicus) on the "Serola Bank" (Western Mediterranean Sea off Barcelona). *Scientia Marina*, 62, 295-299.

Schwinghamer, P., Gordon, D.C., Rowell, T.W., Prena, J., McKeown, D.L., Sonnichsen, D., and Guigne, J.Y. 1998. Effects of experimental otter trawling on surficial sediment properties of a sandy bottom ecosystem on the Grand Banks of Newfoundland. *Conservation Biology*, 12, 1215-1222.

Stratoudakis, Y., Fryer, R.J., Cook, R.M., Pierce, G.J. & Coull, K.A. 2001. Fish bycatch and discarding in Nephrops trawlers in the Firth of Clyde (West of Scotland). *Aquatic Living Resources*, 14, 283-291.

Tuck, I.D., Atkinson, R.J.A. & Chapman, C.J. 2000. Population biology of the Norway lobster, *Nephrops norvegicus* (L.) in the Firth of Clyde, Scotland II: fecundity and size at onset of sexual maturity. ICES Journal of Marine Science, 57, 1227-1239.

Thrush, S.F., Hewitt, J.E., Cummings, V.J., Dayton, P.K., Cryer, M., Turner, S.J., Funnell, G.A., Budd, R.G., Milburn, C.J. & Wilkinson, M.R. 1998. Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Adaptations*, 8, 886-879.

Tufail, A., Meadows, P.S. McLaughlin, P. 1989. Meso- and micro-scale heterogeneity in benthic community structure and the sedimentary environment on an intertidal muddy-sand beach . Proceedings of the *22nd European Marine Biology Symposium*, Barcelona. *Scientia Marina* 53: 319-327.

Glasgow Naturalist 2002. Volume 24. Part 1. Pages 83-91.

A NEW SPECIES OF PARASITIC COPEPOD, *SPHAERONELLA KEPPELENSIS* N.SP. (SIPHONOSTOMATOIDA: NICOTHOIDAE), FROM THE AMPHIPOD *ORCHOMENE NANUS* (KROYER, 1846) IN THE FIRTH OF CLYDE, SCOTLAND.

Myles O'Reilly
Scottish Environment Protection Agency
South West Area, 5 Redwood Crescent, Peel Park,
East Kilbride G74 5PP
e-mail: myles.oreilly@sepa.org.uk

INTRODUCTION

The copepod genus *Sphaeronella* Salensky, 1868 contains over 70 species which live as parasites mainly within the marsupium of marine peracarid crustaceans. Over 40 species are recorded from amphipods (Costello & Myers,1989) with around a dozen of these from amphipods in British Waters (Gotto, 1993, O'Reilly & Geddes, 2000, O'Reilly *et al.*,2001).

In 1993-94 during a study of the amphipod *Orchomene nanus* (Fam. Lysianassidae) undertaken at the University Marine Biological Station, Millport, a small number of the amphipods were found to be infested with copepods which were tentatively identified as *S.callisomae* Scott, 1904 - a species inadequately described almost 100 years ago by Thomas Scott. Of 990 amphipods examined only 8 were found to be parasitised (Moore & Wong, 1996). As the copepod has never been recorded since its original description, the opportunity was taken to undertake a full description of the female, the first description of the male, and also the first description of the copepodite stage. On completion of the descriptive work some new *S.callisomae* material was recovered from the amphipod *Scopelocheiros hopei* (Fam. Lysianassidae) collected in Loch Riddon, in the Firth of Clyde. This amphipod was the original host species of *S.callisomae* and examination of the new material, a mature female and 3 copepodites, revealed an excellent match to Scott's original description. However, it also indicated that the copepod from *Orchomene nanus* actually exhibited significant differences from *S.callisomae*, and indeed from all other known *Sphaeronella* and thus it was considered necessary to establish a new species. The new species is described here. Its congener, *S.callisomae*, will be re-described in a subsequent work.

METHODS

The hosts and parasites were fixed in 10% formalin before transfer to methylated spirit for storage. The copepods were examined as temporary whole mounts in lactic acid or permanent mounts in polyvinyl lactophenol. Drawings were executed at magnifications up to x1,000 with the aid of phase contrast and a camera lucida drawing tube. Host nomenclature follows Costello & Myers (1989).

Sphaeronella keppelensis n.sp.

Material examined

All collected at Keppel Bight, Millport, Isle of Cumbrae, Firth of Clyde (55° 45.75'N, 04°54.48'W), depth 5-6m. (Each sample represents a single host amphipod)

Material deposited in the National Museum of Scotland, Edinburgh:

Sample T33 C9 - 19/4/94 - **Holotype** - 1 female, mature + 1 ovisac (NMSZ 2002.111.1)

Sample T24 B8 - 9/12/93 - **Allotype** - 1 male, mature, mounted on slide (NMSZ 2002.111.2)

Sample T7 A3 - 20/5/93 - **Paratype** - 1 female mature, cephalon dissected and mounted on slide (NMSZ 2002.111.3)

Sample T19 B1 - 22/9/93 - **Paratype** - 1 female immature (NMSZ 2002.111.4), 9 copepodites mounted on slide (NMSZ 2002.111.5), 2 unmounted copepodites (NMSZ 2002.111.6-7), and host amphipod *(Orchomene nanus)*

Sample T26 B3 - 22/2/94 - **Paratype** - 1 female mature + 4 ovisacs (NMSZ 2002.111.8).

Additional material retained in author's collection:

Sample T21 B1 - 26/10/93 - 4 ovisacs (copepod missing!).

Sample T22 B3 - 9/11/93 - 1 female, mature (mounted on slide, poor condition), 1 copepodite dissected and mounted on slide.

Sample T24 B8 - 9/12/93 - 1 female mature (poor condition) + 3 ovisacs, 1 female, immature, mounted on slide.

Etymology:

Named after the type locality - Keppel Bight.

DESCRIPTION

Female (Fig. 1. a, b): Body subspherical comprising a large spherical trunk and a small protruding head. Maximum length 0.85 mm, maximum width 0.72 mm. Ovisacs, irregularly ovoid, detached from female, diameters 0.4-0.5 mm. Cephalon (Fig. 2.a) with naked frontal margin, lateral border margins with fine hairs. First antennae, A.1 (Fig. 2.a,c) relatively short, 3-segmented; proximal segment with 3 setae distally; second segment much shorter without setae, third segment with 9 setae and an aesthetasc (chemosensory appendage). Second antennae, A.2 (Fig. 2.a,b) reduced, comprising a single segment surmounted by a long seta. Oral disc (Fig. 2.a) encircled with fine hairs, with central aperture

through which the tips of the mandibles, Md, are visible. First maxillae, Mx.1 (Fig. 2.a) with 2 long filamentous processes directed anteriorly and a shorter filament on the inner edge. Second maxillae, Mx.2 (Fig. 2.a,d) 2-segmented; proximal segment (syncoxa) robust with stout median process on posterior surface and a row of spinules adjacent to articulation with distal segment; distal segment (basis) forms a curved claw, surmounted with fine curved spine-like process. Maxillipeds, Mxpd (Fig. 2.a) 3-segmented, first segment stout, elongate, with transverse row of fine setules proximally and another row medially on anterior face, second segment considerably smaller with short spine distally on inner edge, third segment curved with minutely tridentate tip. Ratio of maxilliped segments approximately 5:2:1.5. Maxillipeds in paratype (Fig. 2.e) apparently with shorter first segment and 2 spines distally on second segment. The sub-median skeleton (Fig. 2.a) is just visible (dotted) extending back from the base of the first maxillae. Two distinct parallel chitinous ridges are visible between the second maxillae and extend between the base of the maxillipeds to form acute triangular processes. A weak transverse chitinous bar occurs posterior to the maxillipeds.

Trunk (Fig. 1.b) with small spinules scattered throughout. Legs minute (Fig. 3.a,b), consisting of a single short segment with 1-2 setae apically. In the first legs, L.1, the setae are approximately equal in length but the inner seta is much stouter than the outer. Second leg, L.2, a little smaller, the setae are of similar thickness but the outer one is about twice the length of the inner, although 1 seta is sometimes missing. First legs occasionally with an extra seta (Fig. 3.c). The genital area (Fig. 3.d), is mostly covered with spinules through which a pair of oval seminal receptacles and semi-circular genital apertures are visible. The spinules extend posteriorly between the genital apertures towards the caudal rami. The caudal rami (Fig. 3.d,e,f) are short with pronounced conical process on the distal inner edge, and each ramus is ornamented with 2 naked setae, which are about 2-3 times the length of the ramus.

Male: (Fig. 1.c, 2,g) Body small, rhomboidal, maximum length 0.28 mm, maximum width 0.23 mm, head and trunk region each comprising around half of the body. Anteriorly the head is produced medially into a bilobed pseudorostrum. It has pronounced lateral lobes between the pseudorostrum and the first antennae. Lateral lobes, naked ventrally but covered in fine spinules dorsally. The spinule patch is observable even when viewed ventrally through the lateral lobes giving the lobes a dotted appearance. A tuft of these spinules extends around ventrally on either side at the base of the pseudorostrum.

The cephalic shield forms a cape, which partly conceals the base of the second maxillae. The shield margins are ornamented with fine spinules. The exterior border ("shoulder") area is covered with numerous conspicuous nodules.

First and second antennae, oral disc, and first and second maxillae, apparently similar to female, although some details difficult to observe. Maxillipeds similar to female but first segment stouter and with row of fine setules distally at articulation with second segment, and third segment claw is strongly bidentate. The chitinous processes between the base of the maxillipeds are produced posteriorly into two strong spines.

The trunk region is densely covered with long spinules, except for its anterior part. The legs are reduced and very difficult to see. The first legs are mostly concealed by the base of the maxillipeds. The interpretation shown (Fig. 3.h) was gained by focusing through the maxilliped and may not be entirely accurate. Apparently comprising an inner an outer branch with a short rounded lobe between them. The branches have 2 and 3 short apical setae respectively with a longer seta at the base of the inner branch and also on the medial lobe. The second legs (Fig. 3.i) are party obscured by the dense abdominal spinulation. They comprise 2 short simple branches, the inner a little shorter, and each branch with a stout apical seta.

The large oval paired spermathecae are visible through the body wall between the legs. The caudal rami are placed close together at the posterior end of the body. Their structure is similar to the female with the distinctive conical process, though the seta are a little longer.

Copepodite: (Fig. 4.a) Length 0.19 mm (excluding caudal setae), width 0.15 mm, cephalothorax oval, dorsally shield like, covering almost the entire body, only the last 2 segments of the urosome and the caudal rami protruding. The dorsal surface is finely granular with a transverse suture around the midpoint. The dorsal margin has 4 pairs of long setules positioned symmetrically, on anterior margin, and laterally level with the oral cone, mid-dorsal suture, and legs. Frontal border with narrow rostral brim, and a pair of shorter setules ventrally. Lateral margins slightly in-rolled ventrally.

First antennae(Fig. 4.b) similar to adult but setae and aesthetasc on third segment much longer. Second antennae (Fig. 4.c) 4-segmented with 2 terminal setae on distal segment. Oral disc and first maxillae apparently similar to adult. Second maxillae (Fig. 4.d) 3-segmented. First segment stout with row of fine setules, second segment narrow elongate, third segment forming a curved claw. Maxillipeds (Fig. 4.e) 4-segmented, first segment naked, greatly enlarged, second and third segment considerably smaller, third segment with a long seta distally which lies parallel to (and is around 75% the length of) the fourth segment which forms a long slender claw. Ratio of maxilliped segments approximately 9:1:1:6.

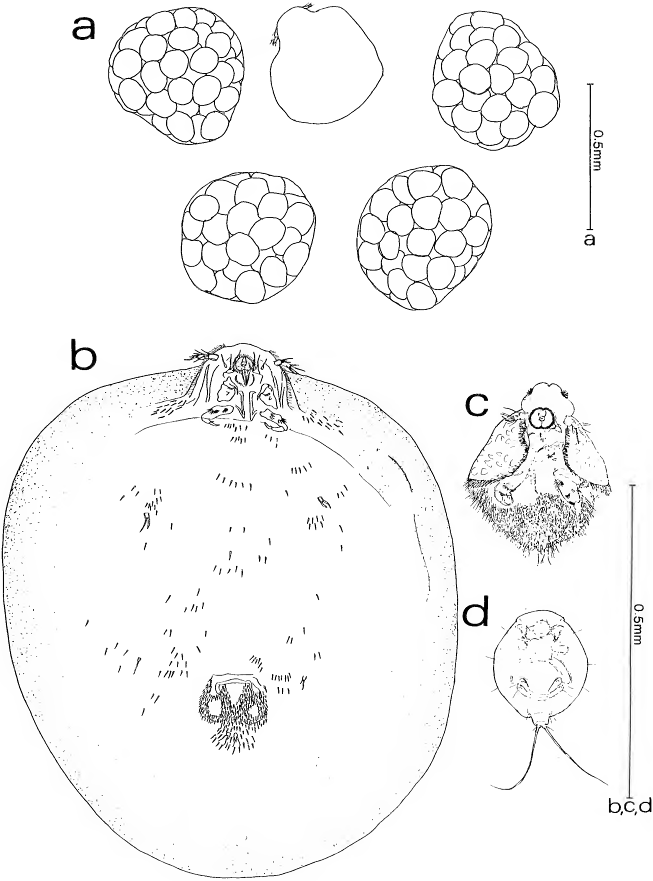


Figure 1: *Sphaeronella keppelensis* n.sp. - **a) Paratype** - Female gravid (T.26 B3) dorsal, with ovisacs, **b) Holotype** - Female gravid (T.33 C9), habitus ventral **c) Allotype** - Male (T.24 B8), habitus, ventral, to scale, **d)** Copepodite (T.19 B1) - habitus, ventral, to scale.

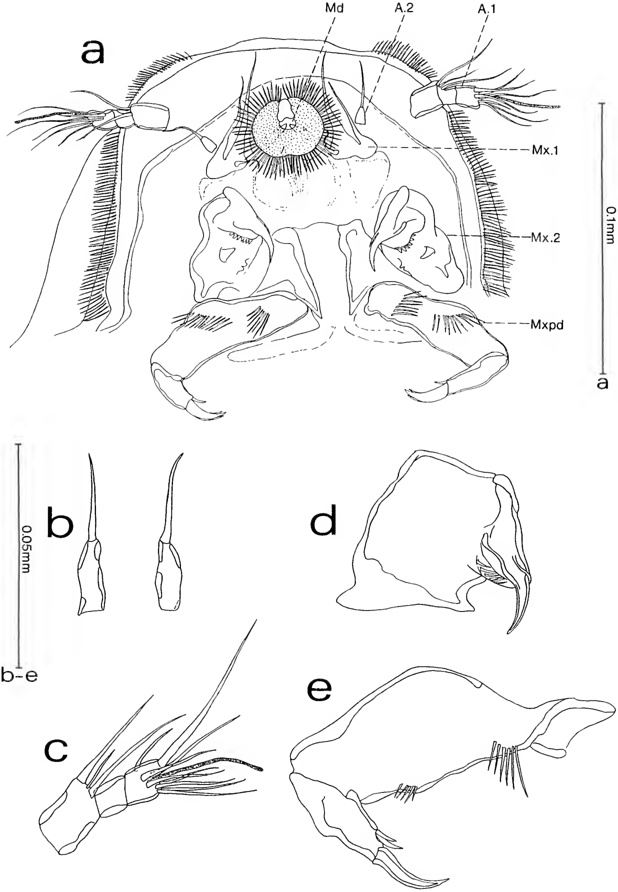


Figure 2: *Sphaeronella keppelensis* n.sp. - **a) Holotype** - Female, mature (T.33 C9) - cephalon, ventral, Md.- mandible, A.2 - second antenna, A.1 - first antenna, Mx.1 - first maxilla, Mx.2 second maxilla, Mxpd.- maxilleped, **b**) **Paratype** - Female (T.7 A3) - right & left second antennae (A.2), **c**) Female (T.24 B8) - first antenna (A.1), left, **d**) **Paratype** - Female (T.7 A3) - second maxilla (Mx.2), left, anterior view, **e**) **Paratype** - Female (T.7 A3) - maxilliped (Mxpd.).

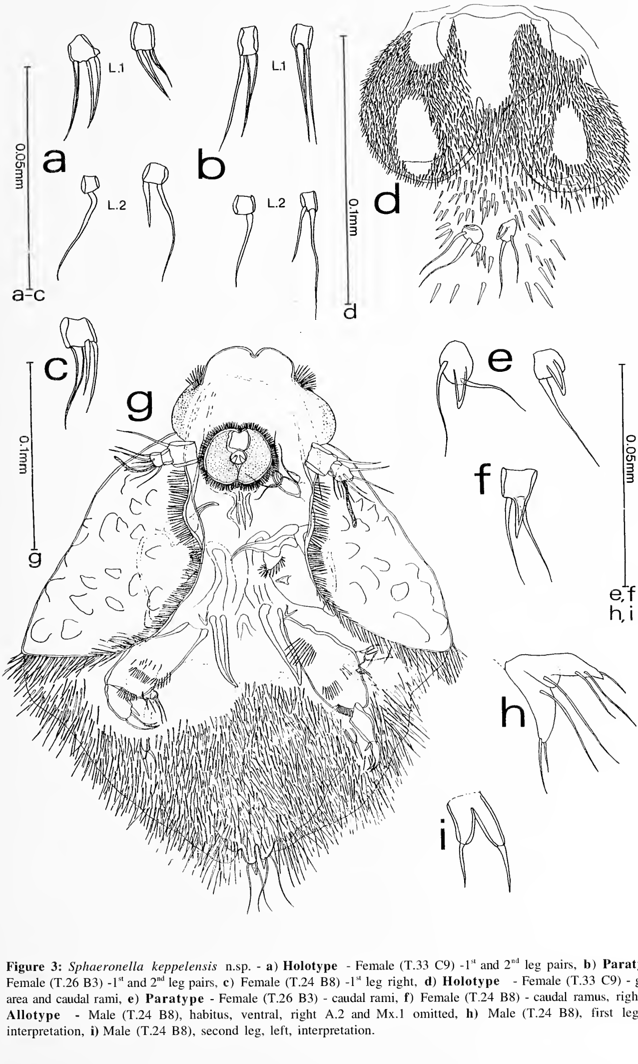


Figure 3: *Sphaeronella keppelensis* n.sp. - **a)** **Holotype** - Female (T.33 C9) -1st and 2nd leg pairs, **b)** **Paratype** - Female (T.26 B3) -1st and 2nd leg pairs, **c)** Female (T.24 B8) -1st leg right, **d)** **Holotype** - Female (T.33 C9) - genital area and caudal rami, **e)** **Paratype** - Female (T.26 B3) - caudal rami, **f)** Female (T.24 B8) - caudal ramus, right, **g)** **Allotype** - Male (T.24 B8), habitus, ventral, right A.2 and Mx.1 omitted, **h)** Male (T.24 B8), first leg, left, interpretation, **i)** Male (T.24 B8), second leg, left, interpretation.

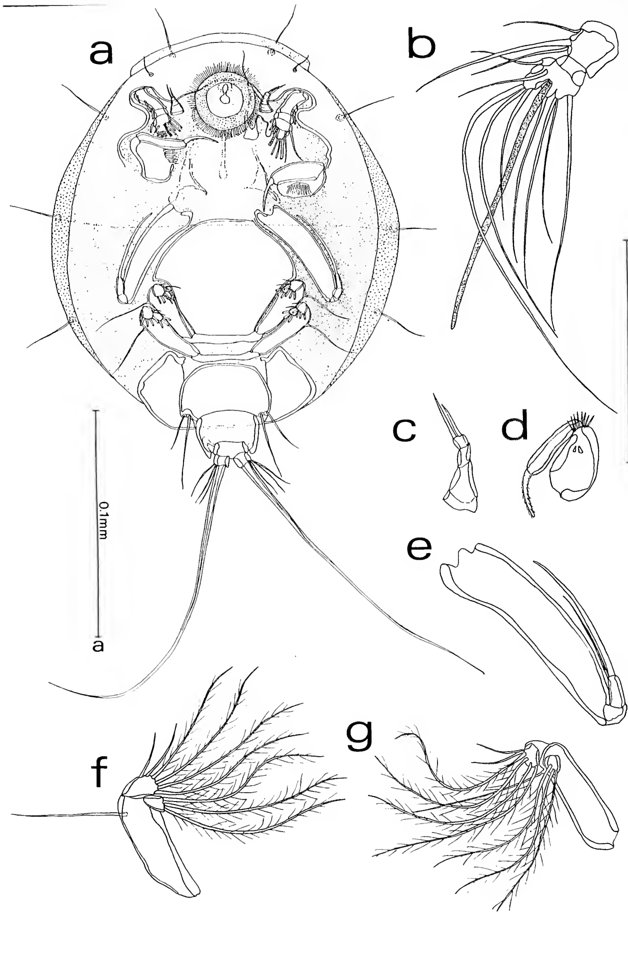


Figure 4: *Sphaeronella keppelensis* n.sp - Copepodite (T.19 B1) **a)** habitus, ventral, (A1 & leg setae truncated), **b)** first antenna (A.1), right, **c)** second antenna (A.2), right, **d)** second maxilla (Mx.2), left, **e)** Maxilliped (Mxpd.), left, **f)** left leg, rami & setae folded inwards, **g)** left leg, rami & setae folded outwards.

A medial prosomal swelling forms an approximate hexagonal shape between the maxillipeds and the legs. It has a smooth surface and is without furrows exhibited by copepodites in many other species of *Sphaeronella.*

There are 2 pairs of biramous legs (Fig. 4.f,g) which are similar in structure, each pair joined ventrally by a narrow intercoxal plate. They have a long basal segment with a single long seta distally on the outer edge. The inner ramus (endopod) is very small with 3 long plumose setae. The outer ramus (exopodite) is a little larger with 4 long plumose setae and 2 shorter naked setae on outer edge. The first legs are incorporated into the cephalosome. The somite of the second legs expands laterally and posteriorly where it form the rear edge of the cephalothorarax.

The urosome comprises 3 segments of decreasing size, and a pair of caudal rami. The first segment has 2 pairs of setae distally on the outer edges. The second and third urosomal segments are un-ornamented. The caudal rami each have 3 relatively short lateral setae and an extremely long inner seta, which is around 75% the length of the cephalothorax.

DISCUSSION

The *S.keppelensis* material was initially attributed to *S.callisomae* on the basis of the unusual combination of a 3-segmented maxilliped with 3-segmented first antennae and 1-segmented second antennae. Its utilisation of a lysianassid host, and its occurrence in the same Sea area added weight to this assertion.

However, Scott's description of his single female of *S.callisomae* does show some significant differences from *S.keppelensis.* The most notable of these is the presence of a "conspicuous tubercle" projecting from the frontal border of the cephalon of *S.callisomae.* In addition its first antennae has only a single setae on the first segment, and a longer third segment with 7 setae (and no aesthetasc). The size and shape of the first and second maxillae also appear to be slightly different and the maxilliped has a shorter basal segment with some spinulation at the articulation with the second segment. Preliminary examination of the new *S.callisomae* female from Loch Riddon substantiates these differences.

Bradford (1975) tabulated the then known species of *Sphaeronella* described from amphipods (41 spp.), isopods (7 spp.), cumaceans (7 spp.), and ostracods (17 spp.) and arranged them into groups based on key features of their morphology. Among these she recognised one group of eight amphipod-infesting species, where the females have a 3-segmented maxilliped (and 3-segmented first antennae), as shown in Table 1.

This group which can informally be called the "*S.giardii* Group" is also characterised by males in which the legs are relatively small with short setae (although males are only known for *S.giardii, S.bonnieri, S.aeginae,* and *S.longipes*). The inclusion of *S.valida* in the group is based on the re-description by Green (1958) who figures a 3-segmented maxilliped, although the original figure of Scott (1905) is clearly 4-segmented. Among five species considered by Bradford as "not well described" and not placed in any group were *S.callisomae* and *S.cluthae* both described from the Firth of Clyde by Scott (1904). They are depicted by Scott with 3-segmented maxillipeds suggesting they ought to belong to the "*S.giardii* Group". The description and figure of the maxilliped of a third species, *S.pilosa* Blake, 1929, is unclear although it shares the same host species (and geographical location) as *S.photidas.*

Table 1. *Sphaeronella* species of the "*S. giardii* Group"

***S. giardii* Hansen, 1897**
Host *Protomedeia fasciata*
Locality Denmark

***S. bonnieri* Hansen, 1897**
Host *Protomedeia fasciata*
Locality West Greenland

***S. longipes* Hansen, 1897**
Host *Ampelisca tenuicornis*
Locality Denmark, British Isles

***S. amphilochi* Hansen, 1897**
Host *Paramphilochoides odontonyx*
Locality Denmark, British Isles

***S. dulichiae* Hansen, 1897**
Host *Dyopedos monacanthus*
Locality Denmark

***S. valida* Scott, 1905**
Host *Megamphopus cornutus*
Locality British Isles

***S. aeginae* Hansen, 1923**
Host *Aeginina longicornis*
Locality Iceland / Faroes

***S. photidis* Blake, 1929**
Host *Photis reinhardi*
Locality New England, USA

It is clear that *S.keppelensis* should also be included in the "*S.giardii* Group" based on the female maxillipeds and reduced male legs. In addition to the 3-segmented maxilliped *S.keppelensis* possesses two features which are unusual within the group; the 1-segmented second antennae and the conical process on the caudal rami. These characters are exhibited by both sexes. The 1-segmented second antennae appears to be shared only with *S.callisomae* whilst the conical process appears to be unique within the group. It is impossible to compare adequately the new *S.keppelensis* material with *S.cluthae*, known by a single female from the amphipod *Harpinia pectinata* (Fam. Phoxocephalidae). Only the habitus (lateral and dorsal) and maxilliped of *S.cluthae* were figured, although the latter is not inconsistent with *S.keppelensis* there is insufficient information overall to draw any inference regarding the affinity of *S.cluthae.*

The male *S.keppelensis* has additional features which also appear to be unique within the "*S.giardii* Group", notably the pronounced bilobed pseudorostrum and lateral lobes of the cephalon and also the conspicuous nodules on the exterior border area. The male has 3-segmented maxillipeds in common with the female but this does not appear to be the case in all males of the "*S.giardii* Group" as *S.giardii* and *S.aeginae* males are figured with 4-segmented maxillipeds. The legs of the male *S.keppelensis* appear to be generally similar to *S.bonnieri.*

The larval or copepodite stage has only been described for around a third of *Sphaeronella* species: 10 from amphipods, 3 from isopods, 5 from cumaceans, and 9 from ostracods (including 2 among the latter for which only the copepodite stage is known).

In almost all *Sphaeronella* copepodites the entire urosome protrudes beyond the cephalothorax, the only exception being *S.bradfordae* Boxshall & Lincoln, 1983 (an isopod parasite) where only the setae of the caudal rami protrude. *S.keppelensis* falls between these two extremes with just the tip of the urosome visible in dorsal view. The legs of the *S.keppelensis* copepodite are also unique with their reduced rami bearing only plumose or shorter simple setae. All other described *Sphaeronella* copepodites have legs with elongate rami (as long as or longer than the basal segment) and possess both plumose setae on the inner edge and spines or simple setae on the outer edge. Similar reduced rami are present in the copepodite of *Sphaeronelliodes vargulae* Bradford, 1975, sole representative of an allied genus from an Antarctic ostracod, but the basal segments of its legs are much shorter and its urosome is only 2-segmented with the caudal rami fused to the last segment. These, along with other unusual features of the mature female *Sphaeronelliodes,* warranted its separation as a distinct genus. It is apparent then that *S.keppelensis* is clearly different from any other described *Sphaeronella* species with both the female and male, as well as the copepodite stage, exhibiting distinctive morphologies.

Most *Sphaeronella* appear to be relatively host-specific occurring in only one or two allied host species. *Orchomene nanus* and *Scopelocheirus hopei* occupy a similar niche as scavengers and were recently found to be the dominant amphipods in carrion-baited traps in the Firth of Clyde (Bergmann *et al.,* 2002). In view of their close association, both phylogenetically and ecologically, it is not surprising that their copepod parasites may also be closely related. Only two other *Sphaeronella* species have been described from lysianassoid amphipods: *S.norvegica* Hansen, 1905 from *Tmetonyx similis* collected in Norway and *S.australis* Boxshall & Harrison, 1988 from the genus *Amaryllis* collected in Tasmania. However, both of these have 4-segmented maxillipeds excluding them from the "*S.giardii* Group".

ACKNOWLEDGMENTS

I am greatly indebted to Professor Geoff Moore and Mr Tym Wong of the University Marine Biological Station, Millport, who kindly supplied the parasitised material of *Orchomene nanus.*

REFERENCES

Bergmann, M., Wieczorak, S.K., Moore, P.G., & Atkinson, R.J.A. (2002). Utilisation of invertebrates discarded from the *Nephrops* fishery by variously selective benthic scavengers in the west of Scotland. *Marine Ecology Progress Series,* 233, 185-198.

Blake, C.H. (1929). New Crustacea from the Mount Desert Region. In: Proctor(1933)(ed.), *Biological survey of the Mount Desert Region*, The Wistar Institute Press, Philadelphia, Part 3, 1-34.

Bradford, J.M. (1975). New parasitic Choniostomatidae (Copepoda) mainly from Antarctic and Subantarctic Ostracoda. *New Zealand Oceanographic Institute,* Memoir No.67, 1-36.

Boxshall, G.A. & Lincoln, R.J. (1983). Some new parasitic copepods (Siphonostomatoida: Nicothoidae) from deep-sea asellote isopods. *Journal of Natural History* 17, 891-900.

Boxshall, G.A. & Harrison, K. (1988). New nicothoid copepods (Copepoda: Siphonostomatoida) from an amphipod and from deep-sea isopods. *Bulletin of the British Museum, Natural History (Zoology)* 54(6), 285-299.

Costello, M.J. & Myers, A.A. (1989). Observations on the parasitism of *Aora gracilis* (Bate) (Amphipoda) by *Sphaeronella leuckartii* Salensky (Copepoda), with a review of amphipod- *Sphaeronella* associations. *Journal of Natural History* 23, 81-91.

Gotto, V. (1993). Commensal and Parasitic Copepods associated with Marine Invertebrates (and Whales). *Synopses of the British Fauna* (New Series) No.46. Published for the Linnean Society and the Estuarine and Coastal Sciences Association by Universal Book Services/Dr. W.Backhuys, 264 pp.

Green, J. (1958). Copepoda parasitic on British Amphipoda (Crustacea), with descriptions of a new species of *Sphaeronella. Proceedings of the Zoological Society of London* 131, 301-313.

Hansen, H.J. (1897). *The Choniostomatidae. A family of Copepoda, parasites on Crustacea Malacostraca.* Pp.1-206, pl.1-13. A.F.Host & Son, Copenhagen

Hansen, H.J. (1905). Two new forms of Choniostomatidae: Copepoda , parasitic on Crustacea Malacostraca and Ostracoda. *Quarterly Journal of Microscopical Science* 48, 347-358, pl.22.

Hansen, H.J. (1923). Crustacea, Copepoda. II. Copepoda parasita and hemiparasita. *Danish Ingolf-Expedition* 3,(7), 1-92, 5pl.

Moore, P.G. & Wong , Y.M. (1996). A note concerning associates of the scavenging amphipod *Orchomene nanus* (Lysianassoidea). *Journal of the Marine Biological Association of the U.K.* **76,** 259-261.

O'Reilly, M.G. & Geddes, D. (2000). Copepoda. pp.217-281, in Vol. 1 of: Foster-Smith, J. (ed.)(2000). *The Marine Fauna and Flora of the Cullercoats District: Marine Species Records for the North East Coast of England.* Vol.1 (546pp.), Vol.2 (561pp.) A Dove

Marine Laboratory Publication, Penshaw Press, Sunderland.

O'Reilly, M., Hamilton, E. & Heaney, L. (2001). New records of amphipods and leptostracans from the Forth Sea area, with notes on their copepod parasites (Siphonostomatoida: Nicothoidae). *Glasgow Naturalist* 23(6), 35-42.

Scott, T. (1904). Notes on some rare and interesting marine Crustacea. *22nd Annual Report of the Fishery Board for Scotland, 1903,* Part 3, pp.242-261, plates 13-15.

Scott, T. (1905). On some new and rare Crustacea from the Scottish Seas. *23rd Annual Report of the Fishery Board for Scotland, 1904,* Part 3, pp.141-153, plates 10-13.

Glasgow Naturalist. 2002. Volume 24. Part 1. Pages 93-103

SHORT NOTES

Glasgow Naturalist. 2002. Vol 24. Part 1. 93

PILL MILLIPEDE *GLOMERIS MARGINATA* ON JURA

Glyn M. Collis & V. Dawn Collis
Brookside House, Fosse Way, Moreton Morrell, Warwick, CV35 9DF.

The Pill Millipede *Glomeris marginata* (Villers) is common and widespread in England, Wales and Ireland, extending to Southern Scotland. It is well known for its habit of rolling into a ball in a manner similar to the Pill Woodlouse *Armadillidium vulgare* (Latreille).

Blower (1985) reports that it is not recorded north of the firths of Clyde and Forth except for one record from Wester Ross (VC 105). This record is presumably unverified since an updated distribution map recently published by the British Myriapod Group *(Newsletter number 32, Spring 2000)*, indicates no records north of the Clyde-Forth line. Mr Blower's records are included in the database from which this map is derived. The only record shown from a Scottish Island is a single 10km square on Arran (Hancock, 1991).

In July 2000 we found *G. marginata* at two sites on the Isle of Jura. One record was from a garden in Craighouse, NR526671, the principal settlement on Jura. The garden was not one that has received much attention other than a regularly mown lawn and some basic tidying. The range of garden plants was small although there were some well-established Fuchsias plus other shrubs. *G. marginata* was found among old garden rubbish under the shrubs.

The other site was low moorland, about 100m from the sea at McDougall's Bay NR443680, not close to human habitation but beside a loop of road that was abandoned when the "main" road was straightened. A short stretch of mortared wall bordered the old road where it crossed a burn, and *G. marginata* was found among rubble at the base of this wall.

References

Blower, J. G. (1985). Millipedes. *Synopses of the British Fauna* (new series) No. 35. The Linnean Society and the Estuarine and Brackish-Water Sciences Association, London.

Hancock, E.G. (1991). Pill Millipede on Arran. *Glasgow Naturalist* 22, 84-85.

Glasgow Naturalist. 2002. Vol 24. Part 1. 93

PLATYARTHRUS HOFFMANSEGGI IN KIRKCUDBRIGHT (VC 73)

V. Dawn Collis & Glyn M. Collis
Brookside House, Fosse Way, Moreton Morrell, Warwick, CV35 9DF.

Platyarthrus hoffmanseggi Brandt is a small blind white woodlouse, well known as an inhabitant of ants' nests in southern Britain. In Harding & Sutton (1985) the only Scottish site recorded for this species is Inverkeithing, Fife (VC 85), with recent records from the same locality where it was found at the turn of the last century by Evans (1900).

On 24th October 1999 *P. hoffmanseggi* was found by us in a nest of yellow ants under a stone on coastal grassland at Knockbrex NX578498. With a favourable climate, the Solway coast is known to support a number of species that generally have a southerly distribution in Britain, including woodlice of the genus *Armadillidium* (Harding, 1975). We found *Armadillidium vulgare* (Latreille) at Knockbrex just a few metres away from the *P. hoffmanseggi* site.

References

Evans, G. (1900). *Platyarthrus hoffmanseggi* Brandt in Fife. *Annals of Scottish Natural History* 35, 186.

Harding, P.T. (1975). *Armadillidium* in South-west Scotland. *Glasgow Naturalist* 19 (3), 175-177.

Harding, P.T. & Sutton, S.L. (1985). *Woodlice in Britain and Ireland.* Institute of Terrestial Ecology, Huntingdon.

Glasgow Naturalist. 2002. Vol 24. Part 1. 93-94

LIME TREE *(TILIA SPP.)* REGENERATION 2001

R.K.S. Gray
"Langdale", 6 Prince Albert Road, Glasgow Gl2 9JX

Previous papers in this Journal have drawn attention to the phenomenon of regeneration of lime trees by seed. Readers will therefore be aware that we are near the northern limit of such natural regeneration in these islands and that consequently its occurrence is worthy of record.

They will also realise that naturally occurring lime trees in this country are either large leaved *(T. platyphyios),* small leaved *(T. cordata)* or common *(T. x europaea)* and that successful fertilisation of the small leaved lime is more temperature sensitive than that of the other two. Also it is important to realise that a suitable temperature at the time of fertilisation is not the only factor that determines successful fertilisation and subsequent germination of lime trees.

The monthly mean temperature maxima for July and August of 1999 were 19.9^{0}C and 19. 1^{0}C respectively. The summer temperatures 1.5 years before germination are considered to be critical in determining fertilisation and subsequent germination of lime seed. The 2001 numbers for *T platyphylos* and *T x europaea* are comparable to those of 1999 when the corresponding 1997 temperature figures were 20.3 and 21.6^{0}C. These increased amounts of lime regeneration at these latitudes are in keeping with the general trend of climatic warming. Regeneration has been observed in Glasgow's West End at the time of writing in April 2002 and a report has been received of regeneration in Milngavie. Observations have also been made of a few survivors in addition to those collated below. Readers are requested to forward information about observations they make to R. Gray.

	T. platyphyllos	*T. cordata*	*T. x. europaea*
Glasgow West End	134	1	225
Outwith Glasgow	6	-	2
Survivors	13	1	5

The table is a summary of the numbers of seedlings and survivors (seedlings which have lived through at least one winter since germination) found by or reported to us in Scotland in 2001. This report therefore extends the records obtained each year since 1997.

Acknowledgements

N.R. Grist, M.H. Hansen and P. Macpherson of the Society and M. Matthews of the Met. Office.

Reference

Gray, R.K.S. & Grist. N.R. (2001). Natural Regeneration of Limes *(Tilia spp.)* in Scotland. *The Glasgow Naturalist* 23 (6), 19-21.

Glasgow Naturalist. 2002. Vol 24. Part 1. 94

ORANGE LADYBIRD *Halyzia 16-guttata* IN HYNDLAND

Norman R. Grist

5A Hyndland Court, 6A Sydenham Road, Glasgow G12 9NR

The short note in the last Glasgow Naturalist (Futter and Futter 2001) drew my attention to the interest of my own sighting of a single orange ladybird on May 22, 1999. I noticed this unusual ladybird in our garden, on a rose leaf I think, one sunny afternoon, collected and photographed it and released it next morning. The photographs were shown to E.G.Hancock, more recently to Richard Weddle and Richard Sutcliffe, and the record with photographic evidence was duly entered as the first in Glasgow for this species in Glasgow Biological Records. The possible association of the species with sycamores was mentioned by Futter and Futter (2001), and there is one mature sycamore in the garden about 12 meters from where I found it. The orange ladybird is primarily a mildew feeder (Majerus 1994), but aphids and honeydew are listed as secondary foods. Most trees in our urban garden are common limes *(Tilia x europaea)* which usually generate much honeydew and black mould on vegetation below, and did so in1999. Are these handsome ladybirds increasing in this northern latitude?

References

Futter, *S.* & Futter, K. (2001). Orange Ladybird *Halyzia 16-guttata* (L.) in Dumbarton. *The Glasgow Naturalist* 23 pt.6, 120.

Majerus, M. (1994). *Ladybirds.* Harper Collins, London.

Glasgow Naturalist. 2002. Vol 24. Part 1. 94-95

SUMMERTIME SWIFTS

Norman R. Grist

5A Hyndland Court, 6A Sydenham Road, Glasgow G12 9NR

For me summer in Glasgow begins when swifts (now *'Common.Swifts') Apus apus* arrive. My first sightings this year (2001) as usual were from the roof garden of our Hyndland flat (NS560 675). I see them clearly silhouetted against the dusk sky over Gartnavel chimney tower, Bingham's Pond and greened areas to its south. This location appears to act as a convenient muster point for them to gather each evening before flying up to perhaps 3000m in order to micro-sleep on the wing without collisions and heading into any wind to avoid drifting too far from their starting point (Bromhall 1980; Blackman 2001). We wonder how they judge the direction of wind when aloft in the dark without reference points during night when it is not always clear and unclouded.

They numbered 3 on May 11th (3 days later than last year's arrival, also of 3). Those last seen also numbered 3 on August 20th (2 on Aug.18 2000) - their departure signalling the end of summer. Their numbers rose to 22 by the end of May with 16 the average maximum in July - August. These totals were somewhat fewer than last year when 24 to 30 were seen in July. Maximum counts in earlier years were 25 ('94), 28 ('95), 20 ('96-97), 18 ('98), 20+ ('99).

It is always a challenge to count these rapidly moving birds about half a kilometer away as they wheel individually and in groups. Most fly in loose pairs and show up black and clear against the bright dusk sky, becoming almost invisible when they turn head-on or tail-on to the observer, to reappear as they bank side-on. Patient scrutiny with the binoculars for several minutes can eventually achieve a reasonably steady count, avoiding double-counting as far as possible and confirmed by consistent counts over several consecutive evenings.

The numbers in early weeks are modest, around 8 to 12, increasing to roughly double in July, then falling in August to about the starting numbers. Perhaps this represents the addition of the young birds of the year that in August fly back to Africa unaccompanied. This leaves their parents free of responsibility to enjoy some remaining weeks here on their own before they too return to Africa to escape our winter. That the youngsters are genetically programmed to migrate on time to the right place without parental guidance is one of those amazing things. Another is the speed with which parental mating and egg laying, and the hatching, fledging and achievement of flight by the youngsters are completed in the few weeks of our midsummer - a tribute to the quantity and quality of our 'aerial plankton', mainly invertebrates windborne over the city.

Clare Darleston, Coordinator of 'Concern for Swifts (Scotland)', has drawn attention to the problems of urban swifts with fewer nesting places available in most of the city. My own observations do not throw much light on this problem, but I hope that my systematic observations and records may

help to document the population trends in this area near Anniesland where she identified some nests.

References

Blackman, S. (2001). *Life's a Breeze*. BBC Wildlife 19 no. 7: 17, citing Bäckman & Alerstam. *Proceedings of the Royal Society of London Series* B 268: 1081-7.

Bromhall, D. (1980). *Devil Birds, The Life of the Swift*. Hutchinson.

Glasgow Naturalist. 2002. Vol 24. Part 1. 95-96

URBAN FOXES IN HYNDLAND, GLASGOW

Norman R. Grist

5A Hyndland Court, 6A Sydenham Road, Glasgow G12 9NR

During the time we have lived here (since 1970) or in nearby Lorraine Rd. (1954-70) we saw no fox until the severe winter of 1996 when we saw a pair in the front garden at 7.30 am on January30th. A neighbour reported seeing two "wolves" a few days before. Having prospected the territory, the foxes adopted it and established a nearby den. Since then they have been resident, breeding, scavenging and interacting with us humans, with cats, squirrels & magpies. Casual observations have made us familiar with the favoured routes and behaviour of the foxes, varying as generations succeeded one another. We have made use of their scavenging for eco-friendly disposal of kitchen scraps, left-over foods (bonanzas around Christmas!) sometimes supplemented by cat-food, dog-food or other items. Pasta & potatoes are ignored, but biscuits, peanuts & cake are readily accepted, and we understand that the foxes enjoyed packet dates put out by a nearby neighbour. This sophisticated town food seems to suit them well - their condition has remained splendid, contrasting with the scrawny foxes seen around Glasgow Airport by Riccardo Lazzarini. Their numbers remained fairly stable with surviving litters of one to three.

Sightings recorded in Table 1 were not from specific, planned observations but from casual sightings from windows or from ground level (garden, car parking, garage), sometimes provoked by hearing the characteristic harsh, high-pitched barking. Peak sightings were in June > July > September. Some encounters were close-range with foxes who showed little fear but much curiosity about our actions and the chance that we might have food. One fox tried to snatch a plastic bag of cake crumbs I was putting out one evening for birds next day. The plastic slipped from his jaws. I tossed him a couple of fragments to show it would not interest him (I thought) but they were gobbled with pleasure - however, I have not taken to buying cake for foxes! On average we put out food scraps, often supplemented with a few dog or cat biscuits, which vanish each night - even occasional quite large bones, which disappear completely - not gnawed as playthings as a dog might do.

Table 1: Times seen/Number seen of foxes, by quarter

Year	Jan-March	April-June	July-Sept.	Oct.-Dec.	Notes
1996	2 / 2	25 / 30	26 / 32	5 / 3+	Mobbed by mapies, June. Dish cleared nightly, Nov.
1997	4 / 5 (+)	5 / 6 (+)	44 / 52	13 / 15	["(+)" = daily sightings of young by neighbours next door]
1998	10 / 11	9 / 9	12 / 15	9 / 10	Grazing peanut/biscuit; Cat spitting standoff in May
1999	11 / 12	14 / 16	14 / 17	11/ 11	17 April 03.00h, squabble, chased off by white cat
2000	6 / 6	20 / 22	29 / 35	15 / 16	
2001	5 / 5	26 / 35	19 / 25	9 / 9	3 June chased etc.

Interactions with other animals include squirrels, one of which clambered up our brick building when disturbed by a fox investigating peanuts dropped for the squirrel. Generally the squirrels avoid them without problems - just as they elude cats, often with contempt, confident in their wide field of vision, speed, agility - and claws. A young fox recently amused us by perching on the roof comer of a garage building to watch a squirrel, a few metres below, enjoying peanuts from a feeder on a tree trunk - so tantalising! Cats rarely chase a fox and a fox rarely chases a cat. After a noisy face-to-face encounter one night both withdrew without actual aggression.

A neighbour's garden provides a sheltered spot for resting, sunbathing, for juniors to play with or without attendant vixen. A wall about 1.5m high provided a sheltered space when heavily overgrown with ivy, and one summer day Mrs Grist while gardening below was surprised to find a young fox staring down at her through the cover

One successful vixen, "Stumpy" with half a tail, first seen in 1997, has reared several families, and showed prowess by chasing off the large white cat which is currently dominant among the felines. Stumpy in turn was chased one June night in 2001 at full racing speed along Linfern Road into our garden and vanished through the shrubby hedge. The large pursuing dog appeared but gave up and left with his owner. Stumpy reappeared and giving a series of loud, sharp calls – danger warning? summoning help? She went back through the hedge, but shortly her big mate Tippy" with the

unusually well-marked white tail tip came through, stared down the track, walked back towards the road & onto the cornr of the garden wall to survey the scene for a few minutes. Satisfied all was well, he trotted off to forage on his own account. Another episode that year was when Stumpy led her two well-grown offspring up steps onto the garage roof and sat gazing out, apparently to show how this vantage point gave a wide view including the length of Linfern Road. The youngsters gambolled with one another, over and round Stumpy, and eventually all departed. Next morning from the stairs I noticed the two alone on the car park, gazing in opposite directions - "what to do next"? As I descended one strolled off behind our building. The other strolled a short distance in the other direction and watched me with relaxed interest as I emerged and opened our garage. It hesitated about approaching in case I had goodies, but decided not and strolled away. Next night again fox barking was heard in 3 directions - suggesting family contact as the youngsters dispersed.

As in many other urban areas in Britain, foxes have thus become an established part of our local fauna, as a stable population presumably in equilibrium with local resources of food and shelter. In the joint national survey by the British Trust for Ornithology and the Mammal Society in the 1km squares of the Breeding Bird Survey, 45 species of mammal were recorded in 1995-2000 (Newson & Noble, 2002). Over the six years the population of red foxes was stable as the fourth most numerous and widely distributed species: the highest counts were for rabbits (1040), brown hare (526), grey squirrel (460), red fox and roe deer each 227 with the fox more widely distributed

Reference

Newson, S. & Noble, D. (2002). BBS Mammal Monitoring. *BTO News* 239, 11-12.

Glasgow Naturalist. 2002. Vol 24. Part 1. 96

A RICH BOTANICAL SITE AT LEADHILLS

P Macpherson

15 Lubnaig Road, Glasgow G43 2RY

Just north of the village of Leadhills, Lanarkshire (VC 77) there is an artificial elongated mound between the road and the burn. It was presumably a slag heap formed when lead was mined in the area. It is approximately 250 yards long and at the north end 25 ft higher than the road but with a 35 ft slope down to the burn. The road rises alongside the mound and is more-or-less at the same level at the southern end. The plateau is 30 yards wide at the north end and 15 yards at the south, and almost horizontal

On the plateau there are small colonies of Frog Orchid (*Coeloglossum viride*), Moonwort (*Botrychium lunaria*), Field Gentian (*Gentianella campestris*), and a very small form of Lesser Meadow-rue (*Thalictrum minor* sl) which has not flowered over a four year period. In addition there are the dandelions *Taraxacum argutum* and *T. subnaevosum* (det. A.J. Richards & A.A. Dudman). Wall Whitlowgrass (*Draba muralis*) is to be found on the stony slopes and Downy Oat-grass {*Helictotrichon pubescens*) on the flat ground at the north end of the mound. All round the area there are carpets of a dwarf form of Water Avens (*Geum rivale*), the subject of a previous report (Macpherson 2000).

It is, therefore, one of the best small sites for rare plants in Lanarkshire.

The Frog Orchid is known from only one other extant site; Moonwort has nine other quadrant records, three of which are on abandoned coal bings; Field Gentian has only one other modern record, a flat area between adjacent coal bings; Lesser Meadow-rue is presumed to be native on rocks at the Falls of Clyde where the plants are much larger; *T. argutum* is the only VC 77 record and *T subnaevosum* the fourth. Wall Whitlowgrass is currently known only from a railway embankment at Elvanfoot and the Downy Oat-grass from eight quadrants.

Reference

Macpherson, P (2000). Abnormal water avens morphology- lead induced? *Glasgow Naturalist* 23, 53-54.

Glasgow Naturalist. 2002. Vol 24. Part 1. 96-97

LESSER HAIRY-BROME AT THE FALLS OF CLYDE

P & LMD Macpherson & J Waddell

15 Lubnaig Road, Glasgow G43 2RY

Bonavista, Heatheryett Drive, Galashiels, Selkirkshire TD1 2JL

In a contract survey of the vegetation of the Scottish Wildlife Trust (SWT) Falls of Clyde Wildlife Reserve, Averts (1997) reported the occurrence of *Zerna* (*Bromopsis*) *benekenii* (Lesser Hairy-brome) on gentle sloping woodland floor and steep banks in the neighbourhood of Corra Castle, Lanarkshire (VC 77).

This plant had not been known there before and its presence in such an area was very surprising as the Falls of Clyde has probably been the most botanised part of Lanarkshire. Further, the SWT reserve has been the subject of a number of previous plant surveys.

In 1999 JW located the site and sent a specimen to a Botanical Society of the British Isles grass referee (RM Payne) who confirmed that it was, indeed, *B. benekenii*. In 2000 a further plant from the site was sent as proof to Prof. CA Stace so that it might be included for the vice-county in the Vice-comital Census Catalogue. This specimen was, in turn, passed on to a brome specialist (LM Spalton) who agreed with the identification.

A search of the surrounding area has since been made (PM & LMDM) and two further colonies discovered which we consider to be *B. benekenii*. At one site of approximately 6x5 metres there were about 20 plants and at a larger one of 14 x 5 m almost 50 were counted. Associated species noted were Great Wood-rush (*Luzula sylvatica*), Wood Sedge (*Carex sylvatica*). Tufted Hairgrass

(*Deschampsia cespitosa*) and Bearded Couch (*Elymus caninus*). Some plants are close to a path and in the past have just been assumed, without thought to be *B. ramosus* (Hairy Brome) which is of widespread occurrence in the reserve and for which there are 27 quadrant records in the vice-county.

We have consulted all the Scottish Floras and Checklists at our disposal and found records only in the *Checklist of the Plants of Perthshire* (Smith *et al.* 1992). They report that the plant occurs in Mid and E. Perth VCs 88 & 89, and instance such well known sites as Keltneybum, Birks of Aberfeldy, gorge near Craighall and Killiecrankie

The plant is included in *Scarce Plants in Britain* (Stewart *et al* 1994), a Nationally Scarce Species in Britain being defined as being recorded in 16-100 10km squares. The publication gives five records for Scotland (VCs 88 and 89) and 29 for England and Wales. The author of the report in that publication (Newton) states that *B. benekenii* is largely confined to woods on shallow chalk, limestone or other calcareous soils in steep valleys, growing in small to medium patches and best on a gentle slope. He stated further, that it is a little known and probably under-recorded species which several competent recorders have found difficult to distinguish from *B. ramosa* with which it sometimes grows. Stace (1997) has also written that it is probably an overlooked species. In general, these criteria apply to its Falls of Clyde occurrence.

In a Scottish context it is the rarest species in the reserve.

The Rev John Lightfoot travelled in Scotland in 1772 and subsequently wrote *Flora Scotica* published in 1777. He referred to the "famous falls" and "celebrated falls" and repeatedly mentioned Corra Linn (with different spellings!), listing some of the plant rarities. This area, together with the falls at Bonnington and Stonebyres became well known for their flora in the 19th century (Mackechnie 1958). The precise locality has, therefore, attracted attention, both from the scenic and botanical aspects for well over 200 years.

We will now look more closely at colonies of "*B. ramosus*" in similar sites in Lanarkshire!

Acknowledgements

We are grateful to Messrs Payne and Spalton for confirming the identification.

References

Averis, ABG (1997). The Vegetation of the Falls of Clyde Wildlife Reserve, Contract Survey for the Scottish Wildlife Trust.

Lightfoot, J (1777). *Flora Scotica*, London.

Mackechnie, R (1958). Plant Recording in Clydesdale, *Glasgow Naturalist*: 18, 3-14.

McMicheal.AC (un-dated- late 19th century). *Notes By the Way: A Descriptive, Historical and Biographical Account of Lanarkshire*, Henry, Ayr.

Newton, AL in Stewart *et al.* (1994). *Scarce Plants in Britain*, JNCC, Peterborough.

Stace, CA (1997). *New Flora of the British Isles* (2nd edition), Cambridge University Press, Cambridge.

Stewart, A, Pearman, DA & Preston.CD (1994). *Scarce Plants in Britain*, JNCC, Peterborough.

Glasgow Naturalist. 2002. Vol 24. Pt 1. 97-98

PREDATOR/PREY RELATIONSHIPS IN AN URBAN ENVIRONMENT.

A.Meadows, P.S.Meadows, &W.Orr

Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, University of Glasgow, G12 8QQ

The pyramid of numbers in any ecosystem is such that there are many organisms at the bottom of the pyramid – the photosynthetic primary producers, progressively fewer as one moves upwards through the secondary producers – the herbivores, and very few at the top of the pyramid – tertiary producers or the carnivores (Elton, 1927; Wynne Edwards, 1962). In a natural ecosystem away from the immediate impact of man the primary producers are the grasses, flowering plants and trees, the secondary producers are often grazing organisms such as deer, gazelles, wild goats, and giraffes (Krebs, 1972; Ricklefs, 1973). The top-level carnivores include the lions, wildcat, eagles and so on. Man imposes a pattern on this by agricultural practice that is expressed to an even greater degree by the construction of villages towns and cities.

The city environment is the oddest ecosystem for any wild plant or animal. Much of it is made of buildings, there are many roads, and the gardens are often so well organised that they are semi-deserts as far as many of our natural flora and fauna are concerned. The top predators are clearly ourselves, but a number of other animals that sit at or near the top of the ecological pyramid have managed to intrude. These include urban foxes, cats – feral or domestic, magpies, and to a lesser extent dogs. So any records of top predators and their interactions with other animals in towns and cities are really very important in enabling us to understand how our somewhat unusual city environment functions in an ecological sense.

We record here two such instances. The first was an avian interaction. It involved three species of birds - the Kestrel, the pigeon and the magpie. The second involved a mammalian avian confrontation. It involved magpies and squirrels, which occurred four years ago..

On the morning of a Saturday in April, 2003, we witnessed an incident outside our ground floor kitchen window at The Mews, 2 Prince Albert Road, Dowanhill, Glasgow. A large bird hit another bird in flight, and then landed in the overhang outside our front door. It was possible to view and photograph the bird through the glass of the front door. It was a Kestrel with a newly killed young pigeon in its claws. The pigeon was photographed. It had the whole of its under surface ripped, with exposure of the two pectoralis major muscles. These are the two muscles attached between the sternum and the humerus bone of the wings, one on each side. They produce the downbeat of the wing that allows a bird to fly. For those nonvegetarians

amongst us, they are also very good eating. Clearly the impact of the Kestrel with the pigeon in flight had killed the pigeon instantaneously The Kestrel left the dead pigeon momentarily, jumped onto a wooden half barrel containing earth, and began to clean its beak on the wood. At that point it saw us and flew off, leaving the dead pigeon on the ground. About fifteen minutes later another bird was seen through the kitchen window. This time it was a magpie that had alighted and begun to eat the dead pigeon. The magpie was encourage to leave, and the dead pigeon put in a polythene bag and hidden under a wood display under the overhang. The bag remained there until darkness fell. However it disappeared overnight. Presumably this was a fox or feral cat.

The kestrel incident, besides being extremely interesting in terms of an urban siting of a highland bird in the city, shows how top predators such as the kestrel, the magpie, and presumably a fox or cat, compete for meat in an urban environment. Interestingly enough, kestrels are now fairly common in Glasgow, and kestrels and sparrow hawks are known to nest on the University campus (personal communication - James Munro).

The second example is interesting because it is an interaction between a mammal and a bird. During October 1998 on the University of Glasgow campus, two magpies were observed attacking two squirrels. The attack developed as follows. The two magpies attacked a single squirrel in a nest on a whitebeam outside the West Medical Building on the main university campus. The nest was about 15 to 20 metres above the ground. The attack involved considerable noise, which first drew the attention of the observer to the event. The noise consisted of screeches and flapping wings. A second squirrel then appeared, apparently from the nest, and joined in the fray. The confrontation between the magpies and the squirrels lasted for about 15 minutes. The magpies eventually ceased attacking and flew off. The squirrels appeared to go back into the nest. The nest was probably a crows nest. The question is what were the squirrels and magpies fighting over, in other words what was in the nest? It is possible that the magpies were using the nest to rear their young, whereupon the squirrels were presumably attempting to prey on the young of the magpie. The other alternative is that the nest may have been used as a dray by the squirrels, in which case the magpies were attempting to prey on young squirrels, and the two adult squirrels were protecting their offspring. Neither alternative is entirely convincing, as autumn is not a time that is normally associated with the breeding of magpies or squirrels.

These two sets of observations on top predators and their activities in a city environment show how important aspects of an animal's predator/prey status can be easily recorded. They also provide good evidence of the way in which the species interact with each other, and indicate that much research is needed on the role of animals such as these in urban environment.

References

Elton, C. 1927. *Animal Ecology*. Sidgwick & Jackson, London.

Krebs, C.J. 1972. *Ecology. The Experimental Analysis of Distribution and Abundance*. Harper Row, New York.

Ricklefs, R.E. 1973. *Ecology*. Thomas Nelson, London.

Wynne-Edwards, V.C. 1962. *Animal Dispersion in Relation to Social Behaviour*. Oliver & Boyd, Edinburgh and London.

Glasgow Naturalist. 2002. Vol 24. Part 1. 98

GREAT SPOTTED WOODPECKERS FEEDING ON THE NECTAR OF RED-HOT POKERS

John Mitchell

22 Muirpark Way, Drymen, G63 0DX

During the warm and sultry weather experienced in early July 2001, A. & D. MacFadyen drew my attention to a family group of Great Spotted woodpeckers *Dendrocopos major* repeatedly visiting a tall clump of South African red-hot pokers *Kniphofia uvaria* in a west Stirlingshire garden. Both adults and a least one juvenile would individually alight on one of the rigid stems of the plant, just below the large flowering head. Binoculuar observations at close quarters showed that the woodpeckers were drinking droplets of nectar from the pendant perianth tubes of the open yellow flowers. Each bird would spend several minutes working its way around a flower head before moving on to the next, occasionally pausing to pick-off and eat an insect which had also been attracted to the feast. Subsequent enquiry produced a similar record of Great Spotted woodpeckers nectar-feeding on Red-hot pokers at Blackhall, Edinburgh, in the summer of 1999 (D. R. McKean, *pers comm.*)

Great Spotted woodpeckers drinking the sap oozing out of the bark of trees in spring are well documented in northern Europe (Cramp *et al.* 1985), but taking advantage of the availability of sugar-rich nectar from a cultivated herbaceous flower in summer is behaviour that appears to have been little observed in the species.

References

Camp, S. et al. (1985). *The Birds of the Western Palearctic* Vol. IV: Terns to Woodpeckers. Oxford University Press.

Glasgow Naturalist. 2002. Vol 24. Pt 1. 98-101

HAECKELIAN RADIOLARIAN MATERIAL AND THE MICROSCOPICAL SOCIETY OF GLASGOW

P. Geoffrey Moore[1] and Richard Sutcliffe[2]

[1]University Marine Biological Station, Millport, Isle of Cumbrae, KA28 OEG

[2] Open Museum Nitshill, Woodhead Road, South Nitshill Industrial Estate, Glasgow, G53 7NN

It is a pleasure to put on record the recent receipt of a box of historic microscope slides most kindly donated to the University Marine Biological Station

Millport (but see below) by Mrs Elizabeth Fletcher, widow of Professor Bill Fletcher (late of the Biology Dept, Strathclyde University). The slides were all prepared by the renowned Professor Ernst Haeckel (1834-1919) of Jena, who is remembered for his 'gastraea- theorie' (1874) in which all metazoan life was traced to a universal gastrula-like ancestor. The earliest substantial treatise on Radiolaria was the comprehensive report by Haeckel (1887), based on samples obtained from the Challenger Expedition (1873-1876). His monograph remained, until very recently, the major source of information on radiolarian diversity and taxonomy (Anderson, 1983).

Not much is known of the links between Haeckel and the Marine Station. He was due to have been the dignitary to have officially opened the Scottish Marine Station [the progenitor of the Millport Station, then based at Granton, nr Edinburgh] in April 1884 but he was ill on the day and, due to his indisposition, Dr (later Sir) John Murray stepped in to do the honours for him (Marshall, 1987; Moore, in press). The wooden slide box (Fig. 1), and each of the 33 slides (number 31 in the sequence 1-34 being missing), which Bill Fletcher had in his safe keeping, however, is clearly stamped with the imprint of *The Microscopical Society of Glasgow.* (Fig. 2) It contains what may be important specimens of Radiolaria, including *Challenger* material. In 1931, The Microscopical Society of Glasgow was subsumed into the Glasgow and Andersonian Natural History and Microscopical Society - now the Glasgow Natural History Society (Sutcliffe, 2001). It seemed only right and proper therefore to return these slides to Glasgow, having noted the Millport link. They have been added to the Glasgow Museums collection (Registered number Z.2001.2)

We append a list of this material so scholars elsewhere may be aware of its existence in Glasgow. The collection consists of stained balsam mounts (although there seems to be much fungal penetration of the preparations) with printed labels to the left side "Radiolarien- Collection von Professor Ernst Haeckel. Jena. 1890." (Fig. 3), and to the right as follows:

Rad. Coll. Nr.1. Polycyttarien-plankton (Pelagisch.) Mediterraneum. Messina. Haeckel.

Rad. Coll. Nr.2. Polycyttarien-plankton (Pelagisch.) Nordl. Atlant. Oc. Canaria. Haeckel.

Rad. Coll. Nr.3. Polycyttarien-plankton (Pelagisch.) Nordl. Atlant. Oc. Bermudas. Haeckel.

Rad. Coll. Nr.4. Polycyttarien-plankton (Pelagisch.) Sudl. Atlant. Oc. Trinidad. Rabbe.

Rad. Coll. Nr.5. Polycyttarien-plankton (Pelagisch.) Sudl. Ind. Oc. Madagascar. Rabbe.

Rad. Coll. Nr.6. Polycyttarien-plankton (Pelagisch.) Nordl. Ind. Oc. Ceylon. Haeckel.

Rad. Coll. Nr.7 .Polycyttarien-plankton (Pelagisch.) Sudl. Pacif. Oc. Elisabeth-I. Rabbe.

Rad. Coll. Nr.8. Polycyttarien-plankton (Pelagisch.) Nordl. Pacif. Oc. Japan. Chall. 229.

Rad. Coll. Nr.9. Acantharien-plankton (Pelagisch.) Sudl. Pacif. Oc. Patagon. Chall. 302.

Rad. Coll. Nr.10. Acantharien-plankton (Pelagisch.) Nordl. Atlant. Oc. Far-Oer. "Triton"

Rad. Coll. Nr.11. Phaeodarien-plankton (Pelagisch.) Nordl. Atlant. Oc. Far-Oer. "Triton"

Rad. Coll. Nr.12. Phaeodarien-plankton (Pelagisch.) Nordl. Pacif. Oc. Sandwich. Chall.256.

Rad. Coll. Nr.13. Phaeodarien-plankton (Pelagisch.) Sudl. Pacif. Oc. Galapagos. Rabbe.

Rad. Coll. Nr.14. Tiefsee-Kerat. Spongien-Skel. *Psammopemma radiolarium.* C. Pacif. Chall. 272. (Pelagisch.)

Rad. Coll. Nr.15. Tiefsee-Kerat. Spongien-Skel. *Cerelasmagyrosphaera.* C. Pacif. Chall. 271.

Rad. Coll. Nr.16. Tiefsee-Kerat. Spongien-Skel. *Psammophyllum annectens.* N. Pacif. Chall. 244.

Rad. Coll. Nr.17. Tiefsee-Kerat. Spongien-Skel. *Stannophyllum zonarium.* C. Pacif. Chall. 271.

Rad. Coll. Nr.18. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 225. W.Pacif. 4475 Fd.

Rad. Coll. Nr.19. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 226. W.Pacif. 2300 Fd.

Rad. Coll. Nr.20. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 265. C. Pacif. 2900 Fd.

Rad. Coll. Nr.21. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 266. C. Pacif. 2750 Fd.

Rad. Coll. Nr.22. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 268. C. Pacif. 2900 Fd.

Rad. Coll. Nr.23. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 270. C. Pacif. 2925 Fd.

Rad. Coll. Nr.24. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 271. C. Pacif. 2425 Fd.

Rad. Coll. Nr.25. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 272. C. Pacif. 2600 Fd.

Rad. Coll. Nr.26. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 273. C. Pacif. 2350 Fd.

Rad. Coll. Nr.27. Tiefseeschlamm. Radiol. Ooze. Chall. Stat. 274. C. Pacif. 2750 Fd.

Rad. Coll. Nr.28. Tiefseeschlamm. Rother Thon. Chall. Stat. 241. N. Pacif. 2300 Fd.

Rad. Coll. Nr.29. Tiefseeschlamm. Rother Thon. Chall. Stat. 244. N. Pacif. 2900 Fd.

Rad. Coll. Nr.30. Tiefseeschlamm. Rother Thon. Chall. Stat. 253. N. Pacif. 3125 Fd.

Rad. Coll. Nr.32. Tiefseeschlamm. Radiol. ooze. Egeria. IV. 1887. Ind. Oc. 2711 Fd.

Rad. Coll. Nr.33. Tiefseeschlamm. Radiol. ooze. Egeria. V. 1887. Ind. Oc. 2779 Fd.

Rad. Coll. Nr.34. Fossile Radiolarien Tertiiiar-Mergel von Barbados (Miocaen. Antillen.)

The slides were presumably produced as standard sets to be sent around interested scholars of the day. An incomplete set of almost identical slides exists within Glasgow Museums' collections. Unfortunately numbers 3, 5, 11, 18, 24, 25 and 31 (of this set) are missing. These have no known connections with the Microscopical Society of Glasgow and their origin was not recorded.

The only other set of microscope slides believed to exist from the Microscopical Society of Glasgow

Figure 1 Wooden slide box containing 33 slides.

Figure 2 Interior of slide box, stamped *Microscopical Society of Glasgow.*

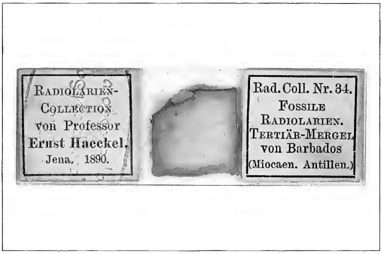


Figure 3 Typical example of one of the slides.

Figure 4 Printed label *Glasgow Microscopical Society.*

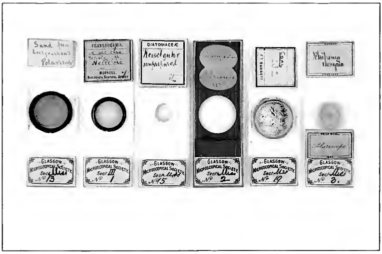


Figure 5 Some examples of slides showing different methods of preparation.

are also in the Glasgow Museums collection (Registration number Z.1983.180). These comprise a set of 24 miscellaneous slides, all marked *Glasgow Microscopical Society*. (Fig. 4) They are also housed in a similar wooden slide box. They were purchased for the Museum from a James Pollok in 1983, and were said at the time to have originally belonged to Mr Pollock's grandfather. This was probably Charles Frederick Pollock M.D., F.R.S.E. (b. c. 1854), who was one of the original Vice Presidents of the Microscopical Society of Glasgow. (King, 1936).

They include such diverse items as the wings of a wasp, pollen grains, chalk and even chemical crystals from claret wine! All the slides are individually labelled with a section and number, and may represent examples of slides which were passed around from member to member.

The slides exhibit different methods of preparation (Fig. 5) and obviously came from several different sources, named preparers including F.T. Barrett; Hornell Biological Station, Jersey; Norman (J. T. Norman , c.1814 – 1893); and E. Wheeler (London). Only two slides are dated (both 1887), but all the slides appear to be of a similar date, from around the time the Society was formed (in 1886). More examples from this set were illustrated in Sutcliffe (2001).

References

Anderson, O.R., 1983. *Radiolaria*. Springer-Verlag, New York, 355pp.

Haeckel, E.,1874. The gastraea-theory, the phylogenetic classification of the Animal Kingdom and the homology of the germ-lamellae. *Quarterly Journal of the Microscopical Society*, 14, 142-165. 223-247.

Haeckel, E., 1887. Report on Radiolaria collected by H.M.S.Challenger during the years 1873-1876. In, C. W. Thompson and J. Murray (Eds), *The Voyage of HMS. Challenger*, H. M. S. 0., London, 18, 1-1760.

King, L.A.L., 1936. The Peter Goodfellow Lecture – A short account of the Microscopical Society of Glasgow. *Glasgow Naturalist* 12(2), 46-49.

Marshall, S.M., 1987. An account of the Marine Station at Millport. *University Marine Biological Station Millport, Occasional Publication* No.4, 133pp.

Moore, P .G., in press., Capt. Alexander Turbyne and the origins of the Marine Station at Millport. *The Linnean*

Sutcliffe, R., 2001 Glasgow's Natural History Societies – an update. *Glasgow Naturalist* 23(6) 62-67.

Glasgow Naturalist. 2002. Vol 24. Part 1. 101

LILY BEETLE (*LILIOCERIS LILII*), IN GLASGOW

Richard Sutcliffe

Open Museum Nitshill, Woodhead Road, South Nitshill Industrial Estate, Glasgow, G53 7NN

Two specimens of the scarlet (or red) lily beetle (*Lilioceris lilii (scopoli)*), were observed mating on royal lilies, *Lilium regale* in a garden in Sween Avenue, Glasgow (NS5859) on 6th May 2002 by Kenneth Boyle. Voucher specimens were collected on 12th May 2002 and were deposited in Glasgow Museums (Day Book number DB.7540), and the Hunterian Museum, Zoology (Entry No. Zoo/18/2002).

This non-native beetle, found throughout Eurasia from the Atlantic to the Pacific, the Middle East and North Africa (Halstead, 1989), has become a serious problem in southern England. Both adults and larvae damage lilies (*Lilium* spp.) and fritillaries (*Fritillaria* spp.).

There were isolated records of the beetle in southern England and Wales in the nineteenth century (Stephens, 1839), but it did not establish itself. There were further occurrences in the London area, Flintshire, Carlisle and Cheshire from 1939 (Fox-Wilson, 1943; Southgate, 1959) and it continued to spread in the 1950s. It had become firmly established in Surrey, Berkshire and Hampshire by the late 1980s (Halstead, 1989). By 2001 it could be found locally in much of southern Britain, as far north as Warton, near Carnforth, Lancashire. The history of the beetle in Britain is described by Cox (2001).

The beetle has become more widespread in England in recent years. This record appears to be the most northerly record of the species so far in Britain, and the first for Scotland.

Since the appearance of an article on the lily beetle in the Glasgow Herald (11 June, 2002) two additional reports have been made in the same area of Glasgow, one in Cathcart and another in Netherlee. This could indicate that a local population may already be or might become permanently established.

Acknowledgements

Thanks to Iain Gibson, Kenneth Boyle, and Geoff Hancock for bringing the record to the author's attention.

References

Cox, M.L., (2001). The Status of the Lily Beetle *Lilioceris lilii* (Scopoli, 1763) in Britain (Chrysomelidae: Criocerinae) *The Coleopterist* 10, 5-20.

Fox-Wilson, G., (1943). The lily beetle *Crioceris lilii* Scopoli: its distribution in Britain (Coleoptera). *Proceedings of the Royal Enomological Society of London* (A) 18, 85-86.

Halstead, A.J., (1989). On the move? *The Garden* 114, 321-323.

Southgate, B.J., (1959). The present status of the lily beetle *Lilioceris lilii* (Scop.) in Great Britain (Col: Chrysomelidae). *Entomologist's Gazette*. 10, 139-140.

Stephens, J.F., (1839). *A Manual of British Coleoptera, or beetles*. London, Longman, Orme Brown, Green and Longmans.

Glasgow Naturalist. 2002. Vol 24. Pt 1. 102-103

RABBIT CALICIVIRUS DISEASE ON AILSA CRAIG, AYRSHIRE IN 2003

B Zonfrillo (1), H Thomson (2) & R A Stewart (1)

1. *Division of Environmental & Evolutionary Biology, Graham Kerr Building, Glasgow University, Glasgow G12 8QQ.*
2. *Glasgow University Department of Veterinary Pathology, Veterinary School, Bearsden Road, Glasgow, G61 1QH*

Following the eradication of Brown Rats *Rattus norvegicus* from Ailsa Craig in 1991, Rabbit *Oryctolagus cuniculus* numbers were noted to have declined considerably through eating some of the distributed Warfarin bait. However, they survived the baiting operations whereas the rats did not and over the next decade their numbers increased once again to near their former population level of some thousands. Pictures of the changes in vegetation were recorded in the paper on the island's flora (Zonfrillo, 1994). Until the first months of 2003 rabbits were again a major detrimental influence on the island's vegetation.

In spring 2003 the island's vegetation was again looking lush and thriving and noticeable was the lack of the usual "carpets" of rabbit droppings on the pathways. Sightings of rabbits were also lower than could have been expected. Something had clearly reduced the numbers of rabbits at least on the lower sections of the island.

During summer 2003 increases in the flowering plants around the lighthouse "flat" area of the island suggested that locally, rabbits had gone completely. Several wizen rabbit corpses were strewn around this area and no live rabbits were observed. On the upper slopes the situation was similar with many corpses but still a few live rabbits around. No deliberate attempt had been made to eliminate rabbits from the island and thus whatever was affecting the rabbit numbers had been contracted under natural circumstances.

By early July 2003 rabbits were seen in only two areas of the island – under the west cliffs and near the summit on the south side. In the latter site BZ and R S found on 4 July a fresh dead rabbit. The liver and spleen were removed for subsequent examination. HT examined the tissue and noted focal hepatic necrosis in the rabbit with micro thrombi in the hepatic blood vessels. There was also massive necrosis in the spleen. The observed damage was typical of Rabbit Haemorrhagic Disease or as it is more specifically known Rabbit Calicivirus Disease (RCD). This disease is a caliciviral infection and is specific to rabbits only.

Examination of the dead rabbit on the island showed no sign of typical Myxomatosis, a disease that occurs on Ailsa Craig about once a decade (BZ pers. obs.) or any other physical injuries.

By August 2003 no rabbits could be found in any of the previous two areas where noted and it was clear that most if not all had been eliminated.

Rabbits were mentioned as being present on Ailsa Craig as early as 1688, where, as on many islands, they were deliberately introduced to provide food for residents or stranded fishermen in times of bad weather (Lawson, 1888). Detrimental effects of rabbits on the island include soil erosion, vegetation modification and the banishment of some edible plants to the sea cliffs as relict populations e.g. the nationally rare Tree Mallow *Lavatera arborea*.

RABBIT CALICIVIRUS DISEASE.

Caliciviral infections such as RCD are a relatively modern phenomenon in wild rabbit populations. Their origin is believed to be from oceanic sources such as shellfish infected by sewage (Smith et al, 1998). RCD was first reported in China in 1984 and soon after in Europe and then Mexico. By 1991 it had reached Australia. Over a few months, it killed around sixty-four million farmed rabbits in Italy alone. The disease has now affected rabbits in over 40 countries and on four continents. Unlike Myxomatosis that in the 1950s, killed 99 per cent of the rabbit population: the kill rate today is often less than 50 per cent. RCD appears to be 100% lethal, at least on constrained isolated island populations and, in captivity, on rabbit farms.

In Europe, the disease appears to follow a two-year cycle. Young rabbits up to five and sometimes eight weeks old that contract the virus do not die from the disease, but develop antibodies and become immune. They survive to become the breeding population in the following year. Maternal antibodies to the virus can be passed to young and confer immunity. However, this immunity is temporary, lasting some twelve weeks. The next generation of young rabbits become susceptible and rabbit calicivirus can spread through the population once again (Munro et al. 1994).

Comprehensive tests in Australia of RCD showed every indication that rabbit calicivirus is specific only to the European rabbit. Hares *Lepus sp.* are not affected. Other research elsewhere into RCD tested 43 different animal species for susceptibility to rabbit calicivirus. The virus did not grow in any of them (Munro et al, 1994). Rabbits usually die 24 hours after the disease is contracted.

IMPLICATIONS FOR THE SCOTTISH FAUNA

How RCD got to Ailsa Craig, the most southerly of Scottish islands, is a matter for speculation. It was certainly not deliberately introduced but may have arrived through fleas on migrant birds or perhaps even on the boots of human visitors. Rabbits contract the disease through sniffing droppings or contact with infected rabbits or from vectors such as fleas or mosquitoes.

If this disease spreads throughout the rest of the Scottish rabbit population on islands or mainland it may have serious implications if rabbit numbers are greatly reduced or completely eliminated. In some cases these may be beneficial as on Ailsa Craig with improved vegetation and knock-on effects on lepidoptera and other invertebrates and the species that feed on them. Elsewhere, predators in some

areas feeding almost exclusively on rabbit e.g. Golden Eagles *Aquila chrysaetos*, Buzzards *Buteo buteo*, Great Black-backed Gull *Larus marinus* (on Ailsa Craig), Red Fox *Vulpes vulpes* and Stoat *Mustela erminea* to name but a few, may have difficulty surviving.

Ecological impact of RCD on native fauna may result in predation on alternative, supplementary or opportunistic prey. If abundance of prey species changes, then it will be recorded in a predator's diet. 'Prey switching' only occurs if the relative availability of a certain prey species is not reflected in the composition of a predator's diet (Murdoch and Oaten, 1975). Predatory species currently locked in to a mainly rabbit diet will therefore "switch" if rabbit numbers rapidly decline.

Three main responses may arise from a predator that a relies upon a prey species such as rabbit for a main component of its diet throughout the year:

a. Behavioural changes, where habitat use and size of foraging range widens, thus increasing effort.
b. Dietary response, when the loss of main prey is balanced by taking alternative species;
c. Reduction in numbers, when food availability reduces predator populations through starvation that in turn promotes their wider dispersal, increases mortality and results in overall poorer breeding success.

At this early stage the future effects of the calicivirus on rabbit numbers in Scotland should be monitored, as should changes in predator numbers or behaviour patterns. Native fauna and flora may benefit or be at risk from a rapid decline in rabbit numbers. Time will tell if long-term immunity to RCD does not emerge and species recovery therefore becomes unlikely. Consequences for some species of the present Scottish fauna may be profound.

REFERENCES

Lawson R (1888). Ailsa Craig : Its History and Natural History. Paisley.

Munro R K and Williams R T Eds. (1994). *Rabbit Haemorrhagic Disease: Issues in Assessment for Biological Control,* Bureau of Resources Sciences, Australia.

Murdoch W and Oaten A (1975). 'Predation and population control.' *Journal of Applied Ecology,* 12: 795-807.

Smith AW, Skilling D E., Cherry N, Mead J H and Matson D O (1998). Calicivirus Emergence from Ocean Reservoirs: Zoonotic and Interspecies Movements. *Emerging Infectious Diseases.* 4.(1) 13 -20.

Zonfrillo B (1994). The Flora of Ailsa Craig. *Glasgow Naturalist.* 22 : 4. 307 - 344.

Glasgow Naturalist. 2002. Volume 24. Part 1. Pages 105-117.

BOOK REVIEWS
Compiled by Ruth Dobson

A GUIDE TO BIRD WATCHING IN THE CLYDE AREA
Edited by Cliff Baister and Marion Osler

Colour photographs on covers by Phil Newman, black and white artwork byThelma Sykes. Sturdy 'ring-bound' volume, 145 pp £10.00 Scottish Ornithologists Club, Clyde Branch 148pp. drawings and sketch maps, 2001. No ISBN £10.00. Available from Cliff Baister, 20 Chapelton Avenue, Bearsden, Glasgow, G61 2DQ. £11.50 (incl. p&p) also from some wildlife outlets in the area.

If you want to watch birds in the Clyde Area this is the book for you! Cliff Baister has drawn on the SOC Clyde Branch for extensive ornithological information on the Area which covers:- City of Glasgow, Loch Lomond, Lanarkshire, Renfrewshire, Dunbartonshire and West Stirlingshire.

After a general discussion of the area covered, the book deals with the individual sites. Each site has a clear map showing where to park, the best route to take and the best viewing locations. The text relating to the site describes the locale and explains how to get there by car or by public transport. Once there, you are advised on the best paths to follow and if hides have wheelchair access and if there are closing times on the reserves. There follows 2 sections on what birds you may see in Spring/Summer and in Autumn/Winter. There are about 80 sites referred to although not all have the full description.

The book acknowledges sponsorship of RSPB, SNH, and The Glasgow Natural History Society.

Ian C McCallum

AMPHIBIANS AND REPTILES: A NATURAL HISTORY OF THE BRITISH HERPETOFAUNA
Trevor J.C. Beebee & Richard A. Griffiths

Harper Collins, London, 2000, 270pp softback with over 70 black and white illustrations. ISBN 0 00 220084 8, £19.99.

This new volume follows Malcolm Smith's *The British Amphibians and Reptiles* (1951, New Naturalist number 20) and Deryk Frazer's *Reptiles and Amphibians in Britain* (1983, New Naturalist number 69). Do we need a new book for such a small part of the British fauna - only 12 or 13 terrestrial species, one or two marine visitors and an assortment of semi-established introductions? Beebee and Griffiths justify this book by the wealth of new information on the British herpetofauna since Frazer's work (their 300 or so references are predominantly post-1980) and by a change of emphasis; they concentrate more on ecology, life histories and conservation than the previous authors. Beebee and Griffiths are well qualified for the task: they are authors of a large number of the cited papers; as they acknowledge, they are both essentially amphibian specialists, but they have consulted widely on their treatment of the reptiles.

This is a very authoritative book and very wide ranging. Though it concentrates on ecology and conservation, the treatment of physiology is up to date and refreshing. I liked particularly their account of ectothermy and thermoregulation: they note that the term 'cold-blooded' is highly misleading and that ectothermic animals may have considerable advantages over the so-called 'advanced' endotherms.

The basic structure of the book is similar to Frazer's. There is a core of five chapters devoted to the main groups in turn: newts, frogs and toads, lizards, snakes and chelonians. Beebee and Griffiths have five additional chapters (compared to Frazer's two) covering amphibians and reptiles in Britain, historical aspects of herpetology (including folklore), basic biology of amphibians and reptiles, aliens and conservation. The conservation chapter, in particular, is a considerable expansion on the earlier treatment, representing the greatly increased importance of conservation in recent times.

From a Scottish point of view, the distribution maps, from the Biological Records Centre, make interesting viewing. Though the book emphasises the modern threats facing reptiles and particularly amphibians, a comparison of Frazer's maps and the new ones suggests most species are commoner than they were 20 years ago. Especially in southern Scotland, most species, particularly palmate newts, common frogs and toads, adders, slow-worms and common lizards are recorded from more squares than in Frazer's maps. Of course, records reflect recorders rather than species abundance, but the increased number of records in southern Scotland is very striking. I only hope that they are correct. Interestingly, Bowles (2001) does report increased numbers and more widespread distribution at least in the case of the common lizard (*Lacerta vivipara*) from his own personal experience.

All in all, this is an excellent addition to the New Naturalist series, not as a replacement for the previous books, but as an update and extension of our knowledge. It is good value for money (only £9 more than Frazer - though softback, rather than hardback). My only quibble is that, unlike Frazer, Ireland has been omitted from the distribution maps. The last time I heard, Ireland was still part of the British Isles…?

Reference

Bowles, F.D (2001) Elusive lizards? Scottish Wildlife 44, 16 - 19.

J.R. Downie

MINDING ANIMALS: AWARENESS, EMOTIONS AND HEART
Marc Bekoff

Oxford University Press, Oxford 2002, 230 pp., hardback with a few black & white illustrations. ISBN 0-19-515077-5. £18.99

Marc Bekoff is a distinguished ethologist (that is a biologist who studies animal behaviour in the spirit of Niko Tinbergen and Konrad Lorenz) who has spent many years investigating the development of individual differences in behaviour. He has concentrated on the role of play in this process, often working with social carnivores such as wolves and coyotes. Like many people studying animal behaviour (and especially the fascinating and enigmatic topic of animal play), he has beome increasingly interested in and impressed by the mental capacities of his subjects. *Minding Animals* is a synthesis of his views on this topic.

The book has two broad, loosely related themes. Firstly, it discusses the nature of the mental processes of animals and, arising from this, the proper way to do science. Secondly, it considers the many ways in which humans abuse animals (including destroying their natural habitats) and what could be done about this. Frankly, I found those parts of the book relating to the first of these themes almost impossibly irritating to read and this has coloured my view of the whole book. To give readers of the *Glasgow Naturalist* a chance to judge for themselves whether to read this book, in this review I have concentrated on summarising the material covered as far as possible without comment, just pointing out briefly at the end what I found so annoying about it.

Minding Animals starts with a glowing forward by Jane Goodall (whose famous work on the social behaviour of chimpanzees has been hugely influential). In his own preface, Bekoff explains how he came to be interested in ethology, animal cognition and welfare and previews the material to be covered. Chapter 1 (*Chasing coyotes and moving yellow snow)* gives a series of examples of the complexity of the behaviour of animals. Bekoff argues from these that we cannot make a clear distinction between human and non-human animals in terms of their cognitive processes and capacity for emotional experience. He cites statistics on the use and abuse of animals (in the food industry and in scientific research), calls for science to be more socially responsible and gives a brief historical account of the ethological approach to behaviour. He stresses the importance of careful comparative studies of the behaviour of wild animals (as practiced by the joint Nobel prize winners Lorenz, Tinbergen and Von Frisch) when compared to more intrusive laboratory-based approaches to the subject. Chapter 2 (*Representing and misrepresenting animals*) discusses human attitudes towards animals, how animals are represented in television programmes and advertisements (for example) and how this influences the way we treat them. In this chapter Bekoff argues that anecdotes about one-off incidents and anthropomorphism (ascribing human motives, feelings and emotions to animals) have a useful role in science. Chapter 3 (*The richness of behavioural diversity*, rightly subtitled "a *potpourri*") gives another series of case studies of more-or-less complex behaviour patterns in animals (from mate choice in insects to self-medication in chimpanzees). Current understanding of the mental processes of animals is covered in chapter 4 (*Animal minds and what's in them*), concentrating on cognitive ethology ("the comparative evolutionary and ecological study of animal minds and mental experiences"). In chapter 5 (*Animal emotions*) Bekoff briefly discusses the nature of emotions and gives more case studies of events that he considers as indicative of strong emotions in animals (not just more simple ones such as fear and anger, but also complex emotions such as joy and embarrassment). He counters the arguments of those who have reservations about ascribing to animals emotions similar to those that humans experience. Chapter 6 (*Play, cooperation and the evolution of social morality*) draws on Bekoff's extensive experience of studying social play in young carnivores and develops his theory that during play young animals learn codes of social conduct that influence their subsequent interactions with other animals (or lay the "foundations of fairness").

Chapters 7 and 8 (*Animal welfare, animal rights and animal protection* and *Human intrusion into animals' lives*) discuss some of the various ways we use animals (from hunting them, to keeping them in zoos and dissecting them in practical classes), the rights that animals have and people's attitudes to exploiting animals. Special attention is given to the use of animals in scientific research. After considering why we need to study animals, Bekoff explains how scientific techniques (even relatively non-invasive ones such as those used on wild animals by fieldworkers) can alter the behaviour of the animals concerned and so compromise any results. Chapter 9 (*Science, nature and heart*) looks in a more general way at how people influence animals (and consequently nature as a whole). It covers extinctions, trade in endangered species, destruction of natural habitat (I did not know that mining for coltan, which is used to make mobile phones, has decimated populations of gorillas and elephants) and abortive reintroduction programmes. The final chapter (*Animals and theology*) is designed to pull everything together; the subtitle "Stepping lightly with grace, humility, respect, compassion and love" sums up the points Bekoff is making here about how we should treat our planet and the animals that inhabit it with us.

There are a number of good things about *Minding Animals*. It is well written, in a highly personal style with very little jargon, which potentially makes it pleasant to read. Bekoff also avoids the assumption that all scientists are male. He takes a

clear look at the practice of science in general and the study of behaviour in particular, honestly and critically identifying ethical and scientific problems raised by work in this area, including his own. He calls for us to make science fun and stresses the importance of educating young people to care for animals and the environment (and to his great credit has been actively involved in this, putting his time and energy where his mouth is). In this context, he eloquently acknowledges and appreciates the fact that today's young people seem to be better at this than many of their parents' generation. Finally, he displays a passionate love for animals and concern for their welfare and for the damage that our species is doing to their habitats.

This is all entirely admirable, so what did I dislike so much about it? First of all, I found it very poorly structured. The text is broken up into short sections with their own titles, some of which work well ("Elephants aren't couches") and others (in my view) do not ("Patient and compassionate altruism: indifference is deadly"). These sections are often repetitive and poorly organised, in the sense that Bekoff keeps coming back to the same points and examples and jumps between different points so that the flow of his argument is obscured. In addition, while purporting to be arguing logically on the basis of facts, at least when supporting the points he wishes to make, Bekoff can be careless about what the evidence does and does not show, and often does not give the reader sufficient information about specific examples to judge for his/herself. To give just one of many examples, in chapter 3 we are told that subordinate monkeys who can perform a learned task effectively when on their own, do so less well in the presence of a dominant companion. This is interpreted as showing that they are deliberately "playing dumb" to avoid trouble, whereas they could simply be too stressed to function well. This misuse of evidence (as I see it) would not matter if the book were simply a personal statement of belief in and concern for the rights of animals, but it does matter since the book is also supposed to be about science. Of course we should recognise the complexity of animal behaviour and be prepared to study and understand it, but over-interpreting data does not help.

Another thing that puts me off this book is the way that Bekoff treats those who disagree with him, for example on the subject of anthropomorphism and the mental states of animals giving them derogatory names; thus people who are not convinced by the value of cognitive ethology are called "slayers". He sets up straw men, quoting out of date positions and implying that views are more narrow and rigid than they actually are. Overall, he comes across as somewhat self-congratulatory; for example, many people study chemical communication, so just what is so outrageously special about his study that involves "moving yellow snow" to see how coyotes use urine marks? He is also patronising; for example, the title *Minding Animals* is quite (in the British sense of "fairly" rather than the North American sense of "very") a clever play on words, but we really do not need to have it explained to us once, let alone twice.

Setting aside my churlish view, in *Minding Animals* Marc Bekoff touches on many very interesting and important issues and the book is informative and challenging to read, whatever one's views on anthropomorphism. At any rate, the cover picture is beautiful. This shows a mother polar bear and her two cubs, snuggled in together with beatific expressions on their faces. For all that I have said, one can see where he is coming from.

Felicity Huntingford

BIRD MIGRATION: A GENERAL SURVEY
Peter Berthold

Oxford University Press, Oxford 2001, 253 pp with many figures. ISBN 0 19 850786 0 (Hbk), 0 19 850787 9 (Pbk) £27.50.

This is the second edition of Peter Berthold's review of bird migration studies, published eight years after the first. The literature on migration is formidable, and it is a brave author who attempts to provide an up-to-date review of recent research. This is an excellent attempt at that task, and like the earlier edition has major sections on the methods used to study behaviour, the various forms that migratory journeys take, the physiological control of migration, and orientation mechanisms. There is a shorter section on the problems of conserving migratory species and a neat chapter that talks the reader through the various remarkable events that an individual warbler will go through during its annual migratory journeys - this brief review of the whole subject I found the most rewarding in the book. There is still a great deal that we do not understand about migration, especially how some bird species are able to navigate so accurately. We really have only the most rudimentary knowledge of how birds might be able to achieve this. The whole book is an excellent review of recent scientific research. My only criticism is that it is rather dull. There is a real sense of wonder and mystery in bird migration. Reg Moreau once calculated that each autumn 5000 million individual small passerines cross the Mediterranean from Europe to overwinter in Africa. The thrill we experience when we see our first swallow of the summer is largely in recognition of the truly awesome journey that this small bird has made from South Africa home to Scotland. It is a pity that scientific writing has so often had the sense of wonder squeezed out of it.

David C. Houston

COLLINS FIELD GUIDE: CATERPILLARS OF BRITAIN AND EUROPE
David J. Carter, illustrated by Brian Hargreaves

HarperCollins, London, 2001, 296 pp., hardback with numerous colour plates and monochrome end plates. ISBN 0 00 219080 X, 16.99.

Reading the publishers' advertisement one might think that this is a new book which was published during June 2001. However examination of the volume itself soon dispels this notion because it is clearly dated 1994 and is simply a corrected version of the original A Field Guide to Caterpillars of Butterflies & Moths in Britain & Europe which first appeared in 1986 and which was favorably reviewed by the present writer in Glasgow Naturalist 21, 1986 p. 227.

There is a differently styled cover and slightly modified title but the text appears identical to that of the original publication except for slight changes in the bibliography and changes in many latin names to accord with modern usage. These changes in names can be readily detected in the main text because amended entries are printed in a slightly less bold type than the originals. Revised names in the captions to the plates also appear in a different type face but there are no differences in the fonts of the food-plant lists or in the general index. There are some mistakes in the application of these corrections e.g. the Emperor Moth, fomerly *Saturnia pavonia* is corrected to *Pavonia pavonia* in the text but appears as *Saturnia* in the index and in parts of the food-plant lists; similarly the old name *Clossiana* appears in the index instead of *Boloria* as in the text.

These criticisms apart, the book still remains the most accessible and useful book of its kind and, packed full of information on the life-histories, distribution, food-plants and diagnostic characteristics of the species considered and with its superb colour illustrations, is highly recommended to all with an interest in caterpillars.

Ronald M. Dobson

GLOBAL WARMING. THE SCIENCE OF CLIMATE CHANGE
Frances Drake

Edward Arnold, London. 2000. 273 pp. Paperback. £14.99 ISBN 0 340 65302 7

We wish we had been able to write this book ourselves. It is concise, simple and beautifully written. In an elegant introduction, Frances Drake reminds us that global warming may be the largest experiment ever undertaken by humankind. His style is such that the book can be read by anyone who has an interest in global warming and yet it has information in it that is new to the specialist. There are eight chapters, starting with basic physical concepts and ending with the need for consensus - surely now even more relevant after the terrible destruction of the World Trade Centre in New York on 11th September 2001.

In chapter one, as elsewhere, the diagrams are clear and extremely good. Frances Drake quickly and expertly describes the climate system, before guiding us through the concepts of energy, radiation, and the Earth's radiation and energy budget. All of these are central to an understanding of the background to global warming. We also discovered for the first time that there are three types of scattering of light - Raleigh, Mie and Tyndall. We should have known this, since we have lectured on related subjects.

The climate system, which is covered in chapter two, is central to an understanding of global warming. Frances Drake describes the general circulation of air and wind in the atmosphere, the hydrosphere - the seas and fresh waters of the world, the significance of gases, oceanic circulation, winds and surface currents, and the deep ocean circulation. This latter is not well known to the non-specialist and is still not fully understood. The second part of the chapter covers subjects which are central to short term changes in weather as well as to longer time-scale global warming effects. These are ocean atmosphere interactions, the El Nino Southern Oscillation (ENSO) and its opposite La Nina in the Pacific Ocean, and the North Atlantic Oscillation (NAO) in the Atlantic Ocean. The last part of the chapter deals with the importance of ice snow on land and at sea, and then the biosphere. Being biologists we would like to have seen more here, but one cannot have everything. Then follows an introduction to the central theme of the book, equilibria, feedbacks and global warming. They are clearly described and set the scene for the remainder of the book.

One of the fascinating aspects of global warming and for that matter cooling, together with associated changes in climate, is that they are happening the whole time. Furthermore they have happened since the earth was first formed. Few people appreciate this or its significance. In other words, change is with us the whole time, and it is ourselves, humankind, who have been lacking in understanding. The next two chapters, chapters three and four, deal with this subject and make compelling reading. Chapter three is entitled 'Past Greenhouses and Icehouses' and chapter four 'Historical Climate Change'. After a quick tour through the major planets in the solar system, the author introduces us to James Lovelock's Goldilocks planet. the Gaia hypothesis and Daisyworld. Daiseworld is a planet colonised only by black and white daisies. Changes in their abundance dictate the planet's temperature - a wonderful example of biological feedback. However the idea has critics. For a detailed analysis read Drake! We then read about the geological climate record and palaeotemperatures, finishing chapter three with the quaternary glacial ice ages and their explanation in astronomical terms -

specifically the Milankovitch Cycle. This is gripping stuff, and makes one understand how our early forebears during the ice ages were governed by extraterrestrial events!

The historical record that Drake considers in chapter four is factually robust. There are many quantifiable changes. Most people know that the River Thames regularly froze in the eighteenth century and that Dutch paintings of that era show heavily snowed scenes that were obviously regular events. This was the little ice age between 1550 and 1800 during which 'Frost Fairs' on rivers were frequent winter events. We are then brought up to the present time with an account of changing climate in the nineteenth and twentieth century. The author explains clearly the external (extraterrestrial) and internal forcings that change climate, including minima and maxima of solar activity. The 11-year solar cycle is fairly well known, but it is much too short to account for changes in climate over a century or more. There appear to be 180, and possibly 400 and 800 year cycles that may fulfill the role. Atmospheric turbidity is also important. This is the amount of dust in the atmosphere, and amongst other things is modulated by large volcanic events such as Krakatoa in 1883. Overcast skies and reduced atmospheric temperatures of a few tenths of a degree follow such events. The last part of chapter 4 is concerned with climate and human history. We thought that this might overlap with what had gone before, but not a bit of it. Here are some fascinating historically accurate case studies including that of the Norse Greenlanders and the western and eastern settlements of the Vikings in Greenland. The settlements were founded in 982 and 985 respectively, when the climate was significantly warmer than now, by up to four degrees. The subsequent history and disappearance of these small colonies is extremely interesting.

Present day observational evidence for global warming is widespread, and as a result there are many models attempting to predict future trends. There is also no doubt about the occurence of global warming since the middle of the nineteenth century. These subjects occupy chapters five and six. The evidence centres on what have now become known as the greenhouse gases - that blanket the earth to such an extent that less heat than normal is irradiated out from the earth. They include carbon dioxide which is natural and of considerable importance. Others include methane, nitrous oxide and the halocarbons. The real question is how much of these effects are anthropogenic, that is are caused by man. A significant part of them are.

One of the continuing disagreements between field and experimental scientists on the one hand, and theoretical scientists on the other, is the usefulness of mathematical models in helping one to understand environmental phenomena. Our own views are somewhere in the middle. Mathematical models can be of great help if handled sensibly. Parameters need to be carefully constrained, and initial conditions defined clearly. Chapter six reviews the model evidence for global warming. Atmospheric general circulation models have received considerable attention, and have merit. Other modeling methods are also covered, such as time-dependent climate modeling. Surprisingly, the chapter is fairly straightforward. This is a tribute to the ability of the author, whose summary statement on page 198 expresses our own view. “Depending on you stance on global warming climate models either provide the best picture of climate change yet available or are a mirage of scientific fact, providing only the illusion of certainty rather than anything concrete”.

Indirect impacts of climate change are perhaps the most difficult to assess objectively, and may be the most important in the long term. Drake considers this rather difficult area in chapter eight, and draws attention to indirect impacts on human populations and on the biosphere. These latter include socio-economic effects, agriculture and health. As the author points out, even our own western technologically advanced societies in the west are not immune from the problems. He draws attention to the need for cost benefit analysis, integrated assessment models, and mitigation options. This is all rather heady stuff, but as usual Drake makes it easy to understand for the intelligent layman. He finishes the book with a chapter entitled ‘The Need for Consensus’. What better way to end – particularly after nine eleven, and the need for cross-cultural dialogue in science the arts and even religion between the nations of the world. A superb book indeed.

Peter Meadows and Azra Meadows

THE NEW ENCYCLOPEDIA OF REPTILES AND AMPHIBIANS

Tim Halliday and Kraig Adler (editors)

Oxford University Press, Oxford (2002). 240pp. Hardback. Extensively illustrated with colour photographs, maps and line drawings. ISBN 019 852 507 9. £ 25.00

This new encyclopaedia is an update of a previous volume (Halliday & Adler, 1986), which is never referred to, but which partly explains the credits to some contributors who have been dead for some time, notably Angus Bellairs. In addition to Tim Halliday and Kraig Adler, both internationally recognised herpetologists, 36 other herpetologists have contributed to the writing, and an army of artists, photographers and editors to the illustrations and lay-out. This is a beautiful and impressive volume.

In recent years, biologists have become alarmed at the catastrophic declines in numbers of both amphibians and reptiles. As might be expected of a book edited by Tim Halliday (he is international director of the Declining Amphibian Populations

Task Force), conservation issues are given full prominence here. At the same time, there has been an explosion in our knowledge of these animals and even an explosion in the number of recorded species. Until recently, it was generally considered that biologists had recorded most of the more conspicuous species in the world, especially the vertebrates, and that the gaps were mainly in the invertebrates, especially insects. However, as Hanken (1999) reported one of the fastest growing species lists is for the amphibians. The old encyclopaedia (1986) reported a total of 4015 species; this new version gives 5,400, an increase of 34% in 16 years; and since this volume went to press Meegaskumbura *et al* (2002) reported over 100 new species of frogs from Sri Lanka alone. The increase in known species of reptiles is a smaller percentage (19%) to 7776, though still considerable.

As the editors point out, it is something of a historical anomaly that reptiles and amphibians are so frequently considered together : in many ways, they are zoological opposites, especially when we compare the water relations of frogs and lizards. However, the comparisons can be very instructive in showing how diverse the evolutionary adaptations can be to mainly terrestrial life of mainly small, low-energy-consuming, mainly predatory vertebrates.

As you might expect of an encyclopaedia, the main structure of the book is an account of the diversity of the two groups, concentrating heavily on living representatives (fossils receive very brief accounts only). Each order (for amphibians : caecilians, urodeles and anurans) receives a full account of general characteristics and biology, then a biodiversity section to family level. Although many individual species are referred to and illustrated, the book (wisely, I think) does not attempt a species or even generic list. There is a little inconsistency in the coverage given to different orders : caecilians, for example, are not given distribution maps for different families, as most other orders are, but this is understandable, given our relative ignorance of this group.

In addition to biodiversity, there are numerous "boxes" and double-page spreads on topics of interest such as turtle nesting, pollution effects, snake venom, temperature dependent sex determination and much more. The book concludes with a glossary of terms, a bibliography and an index.

Many people might regard this as mainly a "coffee-table" book, because of its wealth of beautiful illustrations. But I hope more will read the text, both for information and to raise awareness of the interest and diversity of these two fascinating animal groups and their increasingly worrying plight.

References

Halliday, T.R. & Adler, K. (1986) *The encyclopaedia of reptiles and amphibians*. Allen and Unwin, London.

Hanken, J. (1999) Why are there so many new amphibian species when amphibians are declining? *Trends in Ecology and Evolution* **14**, 7-8.

Meegaskumbura, M. *et al* (2002) Sri Lanka : an amphibian hot spot. *Science* **298**, 379.

J R Downie

WETLAND ECOLOGY - PRINCIPLES AND CONSERVATION

Paul Keddy

Cambridge University Press, Cambridge, 2000. (Cambridge Studies in Ecology) pp. 614.ISBN (hbk) 0 521 78001 2 £90.00 (pbk) 0 521 78367 4 £32.95.

Surely everyone with even a passing interest in output of the BBC Natural History Unit knows that a wetland is that habitat that is formed where the land and the water meet. The very essence of wetlands is that they are the gradation zone from land to water the type of land and water that merge to form the wetland to a very large extent determine its nature. Thus wetlands mean very different things in different parts of the world. The similarities between a Lewisian peat bog and an Indonesian mangrove for example seem superficially tenuous but there is no doubt that wetlands are common, highly productive and thus extremely important habitats. Interestingly according to one figure presented in this book, the whole of Scotland, (with the exception of Aberdeenshire) should be regarded as a wetland. The author (based in Louisiana) has clearly visited Scotland during the rainy season!

One of the principal aims to this volume is to provide an adequate, all encompassing definition and a minimalist classification system for wetlands. In this aim the author devotes over 30 pages of closely typed script but eventually appears to admit to only limited success!

In his second broad aim, to demonstrate the communality of underlying ecological mechanisms between the enormous range of wetland types the author has more success. Drawing on a very wide and varied literature, the author gives a community ecologists view of how wetland systems function. General principals such as zonation, succession, diversity, disturbance and competition are covered logically, clearly and in very considerable depth. Although drawing heavily on wetland examples, these chapters are of equal interest to those interested in other habitat types.

In the final three chapters the author turns to wetland conservation and restoration. As with other topics this is dealt with in depth. On the way to a general conservation and management discussion, the author elucidates functional response relationships and functional classification systems of organisms amongst other relatively complex ecological theories.

Extensively referenced throughout, this work is not for those with a casual interest in the ecology of wetlands, rather it is aimed at the professional researcher and post-graduate student with a good basic grounding in ecological theory. As such it makes a useful addition to the Cambridge Studies in Ecology Series.

Colin Adams

FOSSILS AND EVOLUTION

T.S. Kemp

Oxford University Press, Oxford, 1999, 284 pp. numerous drawings and diagrams.

ISBN 0 19 850345 8 (Hardback); 0 19 850424 1 (Paperback).

Price £14.99

"What are fossils good for?" This question is posed in the opening line of the book. Are they just "a few of the hard bits" of past life that, while of interest as curios, can tell us little, or are they able to make an important contribution to evolutionary theory. This publication sets out to show that evidence from fossils together with knowledge gained from living organisms can be used in partnership. Fossils are important in these studies and without them our knowledge of would be much poorer. Indeed they are our only evidence for the existence of various extinct groups of organisms such as trilobites or dinosaurs. Fossils illustrate the great diversity of past life and the complex pattern of change through geological history that has lead to the life of today.

The subject is set out in a logical and easily followed manner. The book is divided into two parts. The first deals with principles. Following a scene-setting discussion of fundamental ideas Kemp gives a succinct run through of evolutionary theory and of taxonomy. A chapter outlining incompleteness in the fossil record and how to allow for it rounds off this section

The second part deals with practices. Five chapters concentrate on what the author considers as central areas of current palaeobiological research and these are tackled using the principles outlined earlier. The areas chosen are fossils and phylogeny; speciation; rules and laws of taxonomic turnover; mass extinctions: and the origin of new higher taxa.

This is a textbook aimed at students in courses on evolution and palaeontology. While, as the back cover states, it will be of interest to amateurs, it is not a light read. The book provides an excellent synthesis of the current state of evolutionary theory and taxonomy. It brings out the importance of fossils and succeeds in answering the opening question posed by the author.

Alastair Gunning

CORAL REEF FISHES OF THE INDO-PACIFIC AND CARIBBEAN

Ewald Lieske and Robert Myers

Revised Edition, 2001

Collins Pocket Guide, Harper Collins London.

ISBN 0 00 711111 8. 400 pp. over 2,500 coloured illustrations sbk.

This volume is a corrected and slightly expanded version of a first edition, published in 1994. In the mean time the original Lieske and Myers has become the standard handbook for the globe-trotting marine biologist or SCUBA diver interested in fish and fish-watching on coral reefs. It follows the now almost standard arrangement for field guides of having sets of full colour illustrations of typically 10 – 14 related species on the right hand side of each double page spread, and short accounts of each of these species on the left hand-side. The pictures are by and large of very good quality, conveying for most species its typical poise, as well as its colour in life; and the matching text is informative, giving for most species, typical habitat and feeding behaviour, as well as zoogeographical range. Amazingly it covers almost all the species (>2,100) one is likely to see on coral reefs anywhere, in the Indo-Pacific, and also the Caribbean, and given the books pocket guide size and weight, this makes it an indispensable travelling companion for the natural history minded SCUBA diver, or the SCUBA diving biologist.

All told, Lieske and Myers' volume, as it now is, represents a significant achievement, both by the authors, and by the ichthyologists who have informed it. This work corrects scattered errors in the first edition, the most serious of which was the transposition of two of the plates of coloured illustrations. I have yet to find any inaccuracies in this latest edition, and given the evident advisory input of Jack Randall, of the Bishop Museum in Hawaii, with his encyclopaedic knowledge of reef fish taxonomy, I doubt there are many. The advance which this represents is hard for non-specialists to appreciate. The previous and first attempt at a field guide to all coral reef fishes, also published by Collins, was that by Carcasson, available during the 1980s. This was a useful but by no means infallible guide, and was quietly allowed to go extinct. Even this work was an enormous advance on the state of knowledge 30 years before. The problems then of separating species, and determining if they were new to science, or matched the limited descriptions of workers from a century before, is best illustrated by the pitfalls encountered by J.B.L. Smith, the eminent South African ichthyologist, and discoverer of the Coelacanth, whose work on Indian Ocean reef fishes laid the foundations for modern knowledge. Criticism of some of his identifications was reputedly responsible for his suicide. But that some of his determinations turned out to be wrong is scarcely surprising. Among reef fishes, not only may male, female and juvenile have

different coloration, but since sex change is common, all sorts of intermediate forms may be found. Further, while species may vary in exact colouration between regions, to the extent that they have often been described as different species, closely related but distinct species may be less obviously distinguishable. An added problem with marine fishes is that in families such as parrotfishes the colours fade almost immediately on collection, with the result that the original descriptions of many species actually bare little resemblance to their appearance in life. Only the development of underwater photography to an everyday tool has enabled appearance in life of such species to be illustrated with confidence.

A limited number of corrections apart, this revised edition of Lieske and Myers differs from its predecessor mainly in including an additional 44 species. The tactic that has been used is to add one or more new species to the bottom of those left-hand pages where space in the first edition allowed, and to re-jig the corresponding page of illustrations to squeeze in the extra fish. While doubtless this means that some previously omitted, but not unusual, species have now been included, these extra species have only appeared within those relatively few families for which space was available. A few other small criticisms come to mind. The handy maps of the Indo-Pacific and the Atlantic on the inside covers of the first edition, invaluable in interpreting the text descriptions of zoogeographic range (is Rarotonga east or west of Vanuatu?) are missing in the revised edition. And the diagram of reef morphology that appears in Black and White in the first edition, but in colour in the revised one, has so obviously been crayoned in as to make the earlier version look the more professional. All told there are so few differences between the two volumes that I myself have not rushed to acquire the new one. But I would recommend the book as now revised whole-heartedly to anyone with a more than passing interest in reef fish. The one proviso is that most fish inclined divers would be well advised to also carry a more specific guide to the reef fishes of the area that they are visiting at any one time. In Lieske and Myers, as in with many comprehensive guides to the species of whole continents, let alone most of the globe, the reader is often faced with plates of numerous very similar species, that make it a daunting task to track down the one at hand. In practice few of these species will co-occur in any one area, and many non-experts will find it more useful to have to hand a guide that focuses on the species of their chosen destination.

Rupert Ormond

MOTHS

Michael E. N. Majerus

The New Naturalist No. 90, Harper Collins, 2002. 16 colour plates, over 180 black and white photographs or diagrams, 310 pp. ISBN 0 00 220141 0, £34.99.

Each volume of the New Naturalist is awaited eagerly by people of all kinds of natural history persuasion in addition to a strong band of book collectors. It would be natural to compare this new volume on moths with the earlier book of the same title by E.B. Ford (1955). Ford (1946) also wrote the very first volume of the New Naturalist series on butterflies and many of a now ageing generation of naturalists claim to have been influenced in their choice of study or pastime by reading it and subsequent titles in this seminal series. Hopefully this book might have a comparable effect on new students. There is also a widely praised book on moths of more recent origin (Young, 1997) with which to compare this new offering.

Majerus acknowledges Ford as someone who influenced his own career but has not simply updated the earlier approach to the subject animals. Ford did not flinch from introducing quite technical aspects of biology. In his case it was in the burgeoning area of fundamental genetics. For the new century there is more emphasis on ecological genetics and population biology. Thus Majerus pitches in to a discussion on the Hardy-Weinberg law and a number of other aspects used in university-based studies but perhaps not generally employed by field naturalists. In not succumbing to a 'dumbing-down' of these subjects the inclusion of a fairly comprehensive glossary is welcome if not essential. The context of all these is firmly placed in studying the whole organism. Thus the practises of running light traps and wielding nets plus captive breeding are still tools for developing greater understanding of basic biological systems. The considerable effort required for this is necessary for knowledge to advance. This is an idea which needs to be re-inforced in many younger people who believe that gaining access to the internet is a primary source of information.

Chapters include folklore, life history and anatomy, evolution, sex lives, host plants, flight dispersal and distribution, death and defence. Of particular interest is a chapter on melanism. It provides some facts to counter recent claims that the classic case of industrial melanism in the peppered moth, used as a textbook example of evolution in action, is based on invalid (or even falsified) experimental methods. The publicity surrounding this, approaching the level of drama in some quarters, has been seized upon by creationists as "evidence" to disprove Darwinian evolutionary processes. Such events are to the detriment of science and the teaching of science in society.

The colour plates are small, not of the highest quality of reproduction and some have been badly cropped. The insect depicted in Fig 10.1, p.259, is not the well-known yponomeutid pest of cabbages, the diamond back moth, but a species of a different family, Tortricidae probably *Epinotia bilunana*, an innocent birch feeder.

The people who buy this volume, apart from book collectors, are going to get a huge amount of information derived from the author's great experience. Facts are presented and ideas for further investigation suggested. It is possible that the work of Young (1997) appeals more to the person who has already developed an interest in moths, dealing with many topics under multiple headings and often including practical advice for study. Each New Naturalist offering seems to strike new chords with readers regardless of their own subject bias. The library of the dedicated field naturalist includes many titles on many subjects but copies of the New Naturalist volumes will surely always form the core.

During the life of the series this is the second book on moths, with over 2,500 different species in Britain, and quite different from the first. Butterflies (60+ species) have yet to be revisited but there have been three treatments of amphibians and reptiles, a group with just over a dozen species! There does appear to be an imbalance and duplication in respect of coverage and many topics have not been addressed at all such as native woodlands, urban wildlife, alien animals, beetles, history of natural history, estuaries and so on. Perhaps this is one of the joys of natural history - it is endless in its possibilities. Long may the New Naturalist books appear to enlighten us.

REFERENCES

Ford, E.B. (1946) *Butterflies,* The New Naturalist No. 1, Collins, London, pp 368. 56 colour plates, 65 black and white plates or diagrams.

Ford, E.B. (1955) *Moths*, The New Naturalist No. 30. Collins, London, pp 266. 77 colour plates, 90 black and white plates or diagrams.

Young, M. (1997). *The Natural History of Moths.* T & AD Poyser Natural History, London. 271 pp. 16 colour plates, 70 black and white drawings or diagrams.

E.G. Hancock

THE SHIELDING AND DROVE WAYS OF LOCH LOMONDSIDE

John Mitchell

Produced by Jamieson and Munro in association with Stirling Council Library Service. ISBN 1 870 542 43 6, 2000, 31 pp. black and white photographs, £2.95 Obtainable from Shiela Miller, Stirling Council Library Headquarters, Borrowmeadow Industrial Estate, Stirling Council, FK7 7TN.

This attractive and very informative pamphlet gives the history of shieldings and identifies their sites in the area. It likewise deals with the movement of Highland Cattle along the drove ways to fairs in the Central Belt and gives the locations of such roads in the area. Although detailed map references are added, sketch maps would have been an extra help.

Ruth H. Dobson

TREES OF BRITAIN AND NORTHERN EUROPE

Alan Mitchell, illustrated by John Wilkinson

Harper Collins, London. New Edition 1988, reprinted 2001, pp. 228, over 600 tree illustrations in colour. (Collins Pocket Guide). ISBN (pbk) 0 00 219857 6, £14.99

This book was fully reviewed in the "Glasgow Naturalist" 21, pt 4, 1988, the only obvious difference between the two printings being the design on the cover and the price (twice that of 1988), while colour reproduction has been improved somewhat. It continues to be a very good book for use in the field with compact but comprehensive information, numerous colour illustrations and a light but hard wearing cover. It is still good value for £14.99

Ruth Dobson

THE BROADS

Brian Moss

New Naturalist No.89. Harper Collins, London, 2001.392 pp., 29 colour and numerous black & white illustrations including maps. Softback ISBN 0 00 712410 4, £19.99; hardback ISBN 0 00 220163 1, £34.99.

Professor Moss's welcome book *The Broads* takes quite a different approach to the subject than its 1965 predecessor with the same title in the well respected "New Naturalist' series. Gone, for example, are the old-style check lists of species - which in most cases were probably far from complete - to be replaced by a more detailed environmental account of this outstanding waterscape in East Anglia. The author discusses all aspects of the history of the Broads, from their creation to the present time. The ills which have beset these unique wetlands brought on by the effects of modern day living, together with legislative and management solutions to the problems, are thoroughly aired. Up-to-date and extremely readable, this book is unreservedly recommended.

As any enthusiast of the "New Naturalist' series will confirm, the earlier version of *The Broads* by E.A. Ellis is now a much sought after collector's item, with anything up to three figures asked for a clean second-hand copy still wrapped in its dust jacket. So, although the price of the hardback of this new work may seem a trifle expensive, throw caution to the wind and go for it.

John Mitchell

COLLINS BIRD GUIDE

Killian Mullarney, Lars Svensson, Dan Zetterström Peter J. Grant

Harper Collins, London, 2000. (Large Format Edition) ISBN 0 00 7100 82 5, (hbk) 398 pp. Over 3,500 painted illustrations, £29.99

An A4 sized version of the smaller original guide reviewed in The Glasgow Naturalist three years ago. Essentially this is a field guide that would require a vehicle to transport it around. What is to be gained in producing an over-sized field guide to Europe's birds? Actually quite a lot - the illustrations are bigger and therefore more detailed and shows better the artists work, and the text has also been revised and enlarged. Unfortunately some species treatments have not been brought up to date -such as the "Mediterranean Shearwater" - now regarded as two species. This apart, the illustrations are excellent and this larger edition perhaps serves as more of a reference work for the home library than a field guide. It would no doubt also benefit those who suffer with failing eyesight. At £29.99 it is quite expensive but probably represents good value at today's prices.

Bernard Zonfrillo

SMALL FRESHWATER CREATURES

Olsen, Sunesen and Pedersen

Oxford Natural History Pocket Guide, Oxford University Press, Oxford 2001, 229 pp over 800 colour illustrations. Hardback, ISBN-0-19-850798-4. £12.50.

If, like myself, you find it difficult to pass by a pond, or even a ditch, without peering into the water to discover what small water creatures are lurking on or under the surface, this is the book for you.

The paintings of insects and their larvae of about 4 to a page have plenty of explanatory text. The itemisation is surprisingly extensive, covering moths whose larvae feed on water plants, flies, wasps, spiders, worms, leeches, sponges, amphibians, and snakes etc. Perhaps more interesting are the specialised habitats which are described in detail, such as, animals on floating leaves, animals on the surface film and animals on stones in streams.

Although some locations are given, the coverage of the book is Northern Europe which could lead to misidentification. I think an improvement would be for the description to be followed by abbreviations indicating countries where the species are found. If you are trying to identify a fly or beetle you may well not find it listed as the total number of animals listed is only 500.

Ian C McCallum

SMALL WOODLAND CREATURES

Olsen, Sunesen and Pedersen

Oxford Natural History Pocket Guide, Oxford University Press, Oxford. 207pp over 900 colour illustrations. Hardback, ISBN- 0-19-850797 6, £12.50.

This is an attractive field guide with paintings of more than 900 creatures you are likely to come across in a walk through the woods. All the usual creatures are covered :- butterflies, moths, beetles, wasps, spiders, slugs, snails, ants, dragonflies, flies, hoppers, bugs etc.

There are excellent sections on environments. Anyone who collects fungi is soon aware that fungi carry its own fauna, when various beetles and maggots start to appear from the collection. There are other environmental sections on ant heaps, Dutch elm disease, carrion and galls. Perhaps the section that will be of most interest to people is the section on invertebrates which attack people.

The only comment I would make which also applies to the companion volume is that it would be helpful if country locations were indicated by abbreviations after the entries.

Ian C McCallum

ANIMAL TRACKS AND SIGNS

Band Preben and Dahstrøm Preben

Oxford University Press, Oxford, 2001. 264pp, hardback with numerous colour photographs, colour illustrations, drawings and diagrams. ISBN 0 19 850 796 8, £10.00.

This is a well written guide to the signs left by the animals and birds which frequent Europe. These signs range from gnawing, burrowing, territorial marking, droppings, pellets and animal remains. The difference between "barking" and "fraying" by deer was clearly explained. Particularly fascinating was the chapter on droppings, something that even those who seldom leave an urban environment will find useful, enabling, for example, in identification of excrement of the house mouse. This book is a real "eye-opener" to the presence of life that often goes unnoticed. The illustrations, photographs and diagrams are of high quality and the cross-referencing within the text is extremely useful as is the index. The book is pocket size and is ideal for taking on field trips and will be a valuable tool for both the general reader and the experienced naturalist.

Margaret M.H. Lyth

CONSERVATION BIOLOGY

Andrew S. Pullin

Cambridge University Press, Cambridge, 2002, 345pp., softback with numerous illustrations. ISBN 0 521 64482-8, £27.95.

Andrew Pullin has taught Conservation Biology at the Universities of Keele and then Birmingham for a good many years. This book is constructed from that experience and is intended as an introductory text for undergraduates. He is quite explicit about attempting to provide a competitor to the prevailing texts (Primack; Meffe and Carroll) whose emphasis is predominantly North-American.

The book concentrates on conservation biology as an applied science that has grown out of ecology. Pullin writes "The relationship of conservation biology to ecology is rather like that of emergency surgery to health care... It is a crisis discipline in which action must be taken despite lack of sufficient knowledge. Because to wait would mean certain destruction". This means that conservation is necessarily value laden, but Pullin regards this as true of most applied sciences. Despite this, the book deliberately only touches on the legal, political, economic and social aspects of conservation. Pullin claims that these aspects are "often covered inadequately in conservation biology and I did not want to repeat the mistakes".

The book has 15 chapters, divided into three sections: 1- two introductory chapters on biodiversity and the characterisation of ecosystems; 2- four chapters on the threats to biodiversity: habitat disturbance, habitat loss, non-sustainable resource use; 3- nine chapters on conservation biology: its development as a science, and the various aspects of its implementation such as species and habitat protection, *ex situ* and *in situ* measures and restoration ecology. A key chapter (in my view) is on Conserving the Evolutionary Process. Early on, Pullin nails the myth that there is an ecological stability that we should aspire to maintain. But not only do populations fluctuate and migrate: species also naturally become extinct, and new species evolve. Pullin sees a long-term aim of Conservation Biology as the conservation of the evolutionary process itself.

Each chapter closes with a summary, a set of discussion points, a list of further reading sources and a set of web-sites. Each chapter includes one or more Boxes (in blue) where particular examples are given in fair detail. There are many illustrations, including some rather beautiful ones of habitats but, particularly usefully, lots of data figures, tables and distribution maps. The book ends with a reference list to all cited papers and books, and an adequate index.

The book is very clearly written and well aimed at its target audience. The examples used are world-wide, but UK students will find much more that is familiar here than in the competitor North American texts. Part of Pullin's own expertise is in invertebrate animal conservation, and this brings in some nice and less familiar examples.

I would like to make two general criticisms. First, the examples are often given to a rather low level of detail and, although there are sometimes cited avenues for further exploration of the topic, this is not always so. For example, the declining amphibian story is given in a Box with a single reference (Lips, 1998) and no web-site: it would have been easy to give the Declining Amphibian Populations Task Force (DAPTF) web-site. And another: the key captive-breeding story on the black-footed ferret is summarised, but has no references at all: good reviews are available. The American texts do better in this respect.

Second, and more fundamentally, by excluding politics, economics etc., the book pays insufficient heed, in my view, to the importance of people. Without the support of people, conservation efforts are likely to fail and some of the biggest conflicts in world-wide conservation derive from attempts to exclude people from areas of high conservation value. The conservation biology course I teach puts conservation ethics and the role of people at the start, and major international conferences such as the Rio Earth Summit (1992) and the recent replay in South Africa explicitly link environmental issues to development.

Overall, I found this book a very good introduction, and well worth recommending to students. The omissions may well result from the publisher's concern to keep costs down. I hope the book will succeed well enough that a second edition can deal with some of the deficiencies.

Roger Downie

COLOUR IDENTIFICATION GUIDE TO THE GRASSES, SEDGES, RUSHES AND FERNS OF THE BRITISH ISLES AND NORTH WESTERN EUROPE

Francis Rose

Penguin books Ltd, Harmondsworth, Middlesex, 1989, reprinted 2000.240pp. hardback with colour plates showing over 350 species.ISBN 0 670 80688 9, £45.00

This book complements *The Wild Flower Key* previously written by the author in that it covers the groups of vascular plants not dealt with in that work. The aim of the original publication was described as being a guide to plant identification in the field, with and without flowers of the plants of the British Isles and Northwestern Europe. The work continues to have appreciable sales.

The present publication deals with grasses, sedges, rushes, wood-rushes, clubmosses, quillworts, horsetails, adder's-tongues and ferns. Only a few hybrids are included, the author considering that it was not possible to deal with these in the space available and refers the reader to other publications.

It is in hardback form and running to 240 pages, is not particularly suitable for use in the field.

Main and often subsidiary keys are given to aid the identification of plants in each group or sub-group and have been well thought out. The descriptive detail is of high standard and the illustrations are excellent. For the sedges it is particularly useful to have these in colour. Detailed drawings of particular parts are always added where these are important for identification. The amount of work involved in producing the book has been immense.

I have used the publication as an aid to identification throughout the 2001 recording season and found it to work well in practice. It is definitely a useful addition from the point of view of plant identification and is well produced. The only drawback to widespread sales of this book will be the price, but I consider that it is worth the extra to have the illustrations in colour.

During 2001 I had occasion to meet the author and without informing him why I had the book, had him autograph the Society's copy!

P MacPherson

TREES: THEIR NATURAL HISTORY

Peter Thomas

Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, 2000. 286pp., softback with many monochrome drawings and a few black & white photographs. ISBN 0-521 - 45963-X, (pbk) £16.95, (hbk) 0 521 45351 8, £50.00

The aim of the author was to create a book that would describe how trees work, grow, reproduce and die. He has achieved his aim, writing with considerable clarity about the biology of trees, starting with a brief look at the fossil record of conifers and hardwoods. He defines his terms clearly at the outset of the book and the text is supplemented with an adequate number of clear diagrams, summary tables and black and white photographs.

The bulk of the book is devoted to the biology of the main organs of a tree, namely, roots, trunk, leaves, flowers, seeds and fruits. These topics are dealt with in a most comprehensive and lucid manner, bringing together a huge number of interesting facts about trees that would otherwise only be found scattered through many botanical and arboricultural textbooks.

The main difficulty is that of the title. One might expect that a book purporting to deal with the natural history of trees would contain details of their ecology. No reference will be found to this huge aspect of the natural history of trees. Neither the index nor the text contains any reference to the ecological status of different species, such as whether they are light demanders or shade bearers. Aspects of ecology relating to succession such as pioneer, serai or climax species are not approached. An excellent chapter, however, is devoted to trees and the environment, containing comprehensive references to a plethora ofbiotic and abiotic factors impinging upon the life of trees.

This book is a valuable source of reference for anyone interested in trees and how they work.

Bob Gray

PHOTOGRAPHIC GUIDE TO THE BUTTERFLIES OF BRITAIN & EUROPE

Tom Tolman

Oxford University Press, Oxford, 2001, 320pp, over 500 colour illustrations

ISBN 0 19 850606 6	£16.50	softback
ISBN 0 19 850607 4	£35.00	hardback

This book aims to help the user to find and identify butterflies from anywhere in Europe, including the Canaries, Azores, Madeira and all the Aegean islands.

The colour photographs are of very good quality, and despite their small size are clear and backed up by descriptive, although limited text. This appears on the whole to be accurate and informative, and should allow identification of most butterflies. Not all species are illustrated – images of most of the butterflies from the Azores and Madeira are unfortunately conspicuous by their absence.

I like the way there is a different coloured edge to the pages for different families, allowing the reader to quickly locate for example the Pieridae (green) or Lycaenidae (blue), without searching through lots of pages to find them.

The Maps are very clear, with even restricted distributions showing up well, and areas where butterflies may be encountered as migrants, shown in a different colour. Unfortunately a few maps show an over-generalised distribution, e.g. the Pearl-bordered Fritillary, which appears to occur throughout the whole of England, Wales and Scotland, and is described as ‘widespread, locally common’, which it is not. The map for the Brimstone shows the butterfly occurring throughout the Scottish Lowlands. Unfortunately this is not the case, as the text correctly states, it is absent from Scotland.

Despite these few errors, if you are going to be travelling around Europe and want to identify the butterflies you see, I would recommend this book as a useful guide.

Richard Sutcliffe

THE VARIETY OF LIFE
Colin Tudge
Oxford University Press, Oxford, 2002, 684 pp., paperback with numerous monochrome drawings, ISBN 0 19 860426 2, £14.99.

This is a soft back reprint of the original which was favourably reviewed they the undersigned in the *Glasgow Naturalist*, v. 23 pt 5 (p.73) in 2000. The reduction in price from £35 will be greatly welcomed by prospective buyers, but is should be noted that the minor defects point in the review have not been corrected.

Ronald M. Dobson

SEABIRD NUMBERS AND BREEDING SUCCESS IN BRITAIN AND IRELAND, 1999
A.J. Upton, G. Pickerell & M. Heubeck
Joint Nature Conservation Committee, Peterborough, 2000.ISBN 1 86107 507 3, 60 pp. numerous graphs and tables. £10.00

The Seabird Monitoring Programme, under the auspices of the JNCC, and with the collaboration of RSPB and SOTEAG has for a number of years now amassed data on breeding seabirds in the UK and Ireland. Several wildlife groups, Trusts, Government and Non-Government Organisations, as well as amateur and professional ornithologists, feed data into the system from a plethora of sample plots on islands, cliffs, beaches and harbours around the entire coast. Out of it all comes a fairly comprehensive picture of how well our seabirds are faring. This in turn may reflect the condition and productivity of the sea in relation to the seabird's feeding ecology.
Nearly all seabirds are monitored and the data and variability of success between different parts of the country makes fascinating reading. For anyone remotely interested in seabirds or the marine ecosystem this is essential reading and excellent value.

Bernard Zonfrillo

AN ESSENTIAL GUIDE TO BIRD PHOTOGRAPHY
Steve Young
Guild of Master Craftsman Publications, East Sussex, 2001, 166 pp. soft back with over 300 coloured photographs. ISBN 1 86108 193 6, £16.95

If you are looking for an informative and attractive book about how to begin taking bird photographs, then this work by Steve Young is well worth examining. The author is a professional photographer from Liverpool who was inspired by Eric Hosking's famous book *An Eye for a Bird*. Young has gained much experience since he took up bird photography in the 1970s and sets out to instruct and encourage the beginner in this specialist branch of photography. In recent years there have been many books published on bird photography. What is different about Young's book is that he is willing to include a number of his failures as examples of what can go wrong and he demonstrates how to rectify the problems. To this end the book is copiously illustrated in high-quality colour throughout with over three hundred individual bird pictures plus examples of suitable equipment. There is, however, considerable duplication of the bird species illustrated. Common birds are well represented. An impressive series of behavioural studies of the familiar mute swan serve as encouragement to the beginner who may not have the time or equipment to tackle more secretive and rarer subjects. Steve Young himself travels the length and breadth of the country in pursuit of rare migrants and pictures of many of these unusual and spectacular birds are included. I was pleased to notice that the author discourages photography of birds at the nest claiming, correctly in my opinion, that this approach endangers successful breeding. The author also provides plenty of tips to improve your filed craft. This new guide will be a worthy addition to any photographer's library. If you are a keen birder this impressive collection of bird pictures is worth having at any price.

T. Norman Tait

OBITUARY Dick Hunter (1906-2002)

Dick Hunter who died, aged 95, on Sunday 24th February 2002 at 9.00 pm at Drumchapel Hospital, was an Honorary Member of both the Glasgow and Edinburgh Natural History Societies. He was also an active member of the Ramblers' Association, the Scottish Wildlife Trust and a prolific watercolour artist.

Dick was born in the village of Slamannan in Stirlingshire. His mother, of whom he spoke fondly, brought up a family of seven. Life was hard, although it was only on looking back that he realised this. He often spoke of his school days and would tell of the children going to school in the summer with bare feet. He also spoke of some children going to school in the winter with bare feet. He had happy memories of his childhood and could recount vividly conversations he had had when he was five years old. When, for instance, his sister would clypeus to his mother that he had stopped stirring the porridge.

As a young man he worked in the coalmines. Even in later years he was happier in a confined situation rather than on an exposed open hillside. About this time his mother died and his father remarried. After the remarriage, Dick went to live with a married sister in the Coatbridge area. These were the days of the depression and he would say that his sister should have been made Chancellor of the Exchequer because of her ability to run the household on a pittance. At this time he was a keen cyclist and covered the length and breadth of Scotland. After a spell working in a brickworks in Bonnybridge he joined the army in 1939 and was posted to India and Burma where he was a radio mechanic. He would say that he was not a very good soldier. One day after having a cup of tea in a café he left without his rifle. He returned two days later to find his rifle still propped up in the corner where he had left it. His memories of Burma were of the exotic vegetation. He always wanted to revisit Burma when he became a proficient botanist, but never did.

Demobilised, he returned home, constructed tennis courts, and then maintained bowling greens until he retired when he was 75. During his tennis court days one of his assistants 'knew ' the flowers. This sparked an interest in him to study botany and from his mid 40's developed a passionate interest in plant life. He was a regular at many of the Field Centres where he attended courses on flowers, grasses, mosses, sedges, fungi and trees. He joined the Glasgow and Edinburgh Societies and became a very popular and competent excursion leader. Apart from his official outings he delighted in taking groups of friends around Mugdock looking at mushrooms, sedges, plants, and mosses. A large number of people benefited from his good humour, patience, and expert tutoring on these outings.

He was probably happiest in Mugdock where he had intimate knowledge of the locations of the rarer fungi. Most of us remember his gleeful chuckle when he discovered some hidden treasure. He delighted in introducing people to the fascinating world of fungi and explaining how to identify the different species. Occasionally I would ask him to explain the diagnostic features of a particular species. He explained that he recognised a specimen as he would a person. You did not need to know in detail a person's height colour of hair etc. to recognise him; and it was the same with plants.

Occasionally I have seen him discussing in a very learned way with visiting botanical dignitaries on some finer point of mycology. Not bad for some one who started work in the mines!

When he came across a fungus he could not identify he was known to take a spore print, make a watercolour painting of the fungi and sent them off to Professor Roy Watling, who, as always, would be helpful and reply to Dick with the answer.

On his 90th birthday the local Ramblers Group hosted a party for him in Dougalston Golf Club Restaurant on the 13th April 1996, when local artist Priscilla Dorward presented him with a splendid portrait of himself.

The Glasgow Natural History Society also honoured his 90th birthday, at a celebration dinner at the Burnbrae Hotel when the late Camilla Dickson made a cake for him with 90 candles on it. After blowing out the candles he commented 'If I had known that I was going to live as long, I would have taken better care of myself.'

Dick was cremated at Clydebank Crematorium on Wednesday 6th March at 2.30 pm. The service was a Humanist one in accordance with his wishes. He was one of Nature's gentlemen.

I. C. McCallum and J.H. Dickson

PROCEEDINGS 2001

The Chairman, place*, number present, lecturers name and title of lecture are given for most meetings.

*BOB Boyd Orr Building
GKB Graham Kerr Building
WILT Western Infirmary Lecture Theatre

11th January
Bob Gray, GKB, 35, 32nd Paisley International Colour Slide Exhibition, Natural History Section, Compiled by members of Paisley Colour Photographic Club and presented by Wineford Brown and projected by Jim Campbell.

9th February
Prof Jim Dickson, BOB, 235, "Plants and the Tyrolean Iceman: New Discoveries", speaker, Professor Klaus Oegg (joint with Glasgow Archaeological Society).

13th February
Bob Gray, GKB, 45, "The Rhynie Chert", speaker, Dr Lyall Anderson.

27th February
Bob Gray, GKB, 26, 71st AGM. Reports were presented on activities during 2000, and elections held, resulting in appointments as shown opposite. Membership stands at 254, made up of 194 oridinary, 29 family, 17 associate, 4 school and 10 honorary members. There were 3 Council Meetings and the executive met informally as required.
AGM followed by a video taken by the Macpherson family at the launch of the Changing Flora of Glasgow & a talk -"Waders & Wildlife of Arctic Alaska", by Jane Reid.

13th March
Bob Gray, GKB, "The Plants of the Falkland Islands", speaker, Kerry Dalby.

3rd April
Bob Gray, GKB, 48, "Oxford University Expedition to Western Himalayas 2000", speaker, Dr George McGavin.

15th May
Bob Gray, GKB, 30, "Wildlife Crime Detection", speaker, John Simpson.

15th-16th June
BOB, 150th Anniversary Conference; "Alien Species: Friends or Foes".

17th June
Summer Social, Forth & Clyde Canal Trip, Kirkintilloch Followed by meal at The Stables.

18 Excursions took place during the year.

28th September
Bob Gray, GKB, welcomed members to the Exhibition Meeting with Wine and Cheese.

9th October
Bob Gray, GKB, 23, "Pandora's Box - Developing a British Fern Collection", speaker Prof Alastair Wardlaw.

24th October
Dr Jan Lindstorm (of DEEB, University of Glasgow), WILT, 255, "Co-operation in Mammals", Prof T H Clutton-Brock, DEEB/GNHS Annual Lecture, Blodwen Lloyd Binns Lecture.

9th November
Bob Gray, GKB, 31, "Lime Trees at the Border", speaker, Prof Donald Piggott.

13th December
Bob Gray, Glasgow University College Club, Christmas Dinner followed by talk - "Seals and Seabirds of the South Atlantic" given by Dr Dominic McCafferty.

OFFICERS AND COUNCIL
SESSION MMI 2001

President:
Robert Gray, B.Sc., M.I.Biol.
Vice Presidents:
Edna Stewart, B.Sc.
Ian C. McCallum, C.Eng., M.I.C.E., F.I.H.T.
Ruth H. Dobson, B.Sc., M.Sc.
Councillors:
Eric Curtis
Prof. James Dickson, B.Sc., Ph.D., F.L.S., F.R.S.E
Russell Semple
Carole McLay
David D Wylie, B.Sc.
General Secretary:
Kirsty A Kennedy-Wylie, B.Sc., M.Sc.
Treasurer:
Morag Mackinnon, B.A., B.Sc.
Librarian:
Joan Chapman
Editor
Roger Downie, B.Sc., Ph.D.
Section Convenors:
Keith Watson, B.Sc., M.Sc. (Botany)
Richard Weddle, B.Sc. (Computer)
Julian Jocelyn (Geology)
Ian C. McCallum, C.Eng., M.I.C.E., F.I.H.T. (Excursions)
Sandy McNeil (Ortnithology and Photography)
E. Geoffrey Hancock, B.Sc., F.M.A. (Zoology)
Assistant Secretaries:
Catherine D. Aird, M.A., A.L. (Library)
Fiona Giffard, B.Sc. (Minutes)
John Lyth, B.Sc. (Publicity)
Hazel Rodway (Social)
Newsletter Editor: Prof. Norman R. Grist, B.Sc., M.B.Ch.B., F.R.C.P., F.R.C.Path.
Editorial Board:
The Editor
Allan McG. Stirling
Prof. James Dickson B.Sc., Ph.D., F.L.S., F.R.S.E.
Iain C. Wilkie, B.Sc., Ph.D.
BLB Administrators:
Peter Macpherson, F.R.C.P., F.R.C.R., D.T.D.C., F.L.S.

THE GLASGOW NATURALIST - Advice to Contributors.

The Glasgow Naturalist publishes articles, short notes and book reviews. Book reviews are commissioned by the Librarian. Books reviewed are kept in the Society's Library. Articles and short notes should be sent to The Editors, Azra and Peter Meadows, The Glasgow Naturalist, Graham Kerr Building, University of Glasgow G12 8QQ. Short notes are edited by Mr A. McG. Stirling. Articles and short notes are refereed. Acceptance of articles and short notes are the responsibility of the Editors. The journal is published yearly. The subject matter of articles and short notes should concern the Natural History of Scotland in all its aspects, including historical treatments of natural historians.

2. **Short notes** should not normally exceed one page of A4 single-spaced. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new stations for a species, rediscoveries of old records, additions to records in the Atlas of the British Flora, unusual dates of flowering, unusual colour forms, ringed birds recovered, weather notes, occurrences known to be rare, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.

3. **Articles** should be more substantial than short notes. The maximum length should not exceed approx 6000 words including references and equivalent space for tables and references. Longer articles should be discussed with the Editors before submission. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. The text should be divided into sections with sub-headings as appropriate .
(e.g. Abstract, Introduction, Methods, Results, Discussion, Conclusions, Acknowledgements, References)

4. **References** in articles and short notes should be given in full (please do not abbreviate journal titles) according to the following style:
Pennie, I.D. 1951. Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.
Wheeler, A. 1975. *Fishes of the World.* Ferndale Editions, London.
Grist N.R. & Bell, E.J 1996. Enteroviruses. Pp. 381-90 in Weatherall, D.J. (editor) *Oxford Textbook of Medicine.* Oxford University Press, Oxford.

5. **Nomenclature** of vascular plants should be as in Stace, C.A. (1997). *The new Flora of the British Isles*, (Second Edition) Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply.
Please use lower case initial letters for all common names e.g. wood avens; blackbird, unless the common name includes a normally capitalised proper name e.g. Kemp's ridley.
Where giving distribution information by vice-county, use the following style: VC 30.

6. **Submitted manuscripts** (two copies) should be typed double-spaced on A4 paper. Typesetting is greatly assisted if the manuscript can be supplied on a microcomputer diskette. Authors are therefore strongly encouraged to produce manuscripts using a word processor (preferably on a PC-compatible microcomputer). However, to assist amateur naturalists, the Editor can make arrangements to have hand-written manuscripts or typed manuscripts transferred to disc.

7. **Tables** are numbered in Arabic numerals e.g. Table 1: they should be double-spaced on separate sheets with a title and short explanatory paragraph underneath.

8. **Figures**, Line drawings and photographs are numbered in sequence in Arabic numerals e.g. Fig. 1. If an illustration has more than one part, each should be identified as 9a), (b) etc. The orientation of the figure and name of the first author should be indicated on the back. They should be supplied camera-ready for uniform reduction of one-half on A4 size paper. Line drawings should be drawn and fully labelled in Indian ink or dry-print lettering or laser printed. A metric scale must be inserted in micrographs etc. Legends for illustrations should be typed on a separate sheet. The Editors are able to accept a small number of high quality colour photographs for each issue. Please consult the editors before submitting the paper.

9. **Proofs** should be returned to the Editor by return of post. Alterations should be kept to the correction of errors. More extensive alterations may be charged to the author.

10. **Offprints**.Ten offprints and one complimentary copy of the Journal are provided free of charge. Further copies may be purchased, provided that they are ordered at the time the proofs are returned.

11. **Review**. All submissions are reviewed by the Editors or their appointed referees. They are also assessed by the Editors for ethical considerations. Publication may be refused on the recommendation of the Publications Committee.

Front Cover (photograph provided by J. Mitchell) An early French impression of water meadow management, an agricultural practice now lost to Scotland.

Back Cover (photograph provided by J. Maxwell) A female willow tit emerging from the nest cavity with ringed male waiting to feed the nestlings (top); a blue tit approaching an "appropriated " stump cavity with caterpillars (bottom left); female willow tit pauses between feeds (bottom right).


a
b
c

The Glasgow Naturalist

Volume 24 Part 2 2004

Journal of
THE GLASGOW NATURAL HISTORY SOCIETY

GLASGOW NATURAL HISTORY SOCIETY

(formerly The Andersonian Naturalists of Glasgow)

The object of the Society is the encouragement of the study of natural history in all its branches, by meeting for reading and discussing papers and exhibiting specimens and by excursions for field work. The Glasgow Natural History Society meets at least once a month except during July and August, in the University of Glasgow, the Glasgow Art Gallery and Museum, or Hillhead Library.

The present rates of subscription per annum are: for Ordinary Members, £17: Family Members, £3 extra; Junior Members (under 21) £8; School Members, £1. Payment by Direct Debit is encouraged.

Further information regarding the Society's activities and membership application forms are obtainable from the General Secretary, The Glasgow Natural History Society, c/o DEEB, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland. The Glasgow Natural History Society website is http://www.gnhs.freeuk.com/, which also contains details of the Glasgow Naturalist.

The Glasgow Naturalist

The Glasgow Naturalist is published by the Glasgow Natural History Society. ISSN 0373-241X. Price £4.25 plus p.& p (as applicable at the time of posting). The Glasgow Naturalist is free to members.

Editors: Azra Meadows and Peter Meadows, Graham Kerr Building, University of Glasgow G12 8QQ (Tel: 0141 330 6622/6624, Email: gbza31@udcf.gla.ac.uk)

Contributions are invited, especially when they bear on the natural history of Scotland. Full details of how to contribute articles or short notes are given at the end of the volume. A limited number of advertisements can be accepted and enquiries should be sent to the Editors.

This publication is included in the abstracting and indexing coverage of the Bioscience Information Service of Biological Abstracts and the Botanical Society of the British Isles Abstracts.

The following back numbers are available for purchase in their separate parts:

Vols.II - VII (1890-1918); Vols. XIII - XXIII (1937-1999).

Of the earlier Journals the only parts available are:

Proceedings and Transactions of the Natural History Society of Glasgow Vol. II pt. 2; Vol. VI pt. 1; Vol. VII, pt. 3; Vol. VIII, pts. 1 & 2.

Enquiries regarding prices of and orders for any of the above, or for reprints or photocopies, should be addressed to the Librarian: Mrs Joan Chapman, 121 Randolph Road, Jordanhill, Glasgow G11 7DS, Scotland.

Publications of Glasgow Natural History Society

Alien Species: friends or foes? Edited by J.R.Downie (2001). Proceedings of the GNHS 150th Anniversary Conference. Price £10.00 plus p & p.

Bound copies of the following may be obtained from the Librarian at the address above and at the prices shown:

The Flora of the Clyde Area (Original printing). J.R. LEE, Price £11.00 to members of GNHS and to the book trade; £13.50 to others (p. & p. £1.00 extra). This is still the only work of its type and is in diminishing supply. A few unbound copies are available: £5 (p.&p. £1 extra).

The Flora of Ailsa Craig. B. ZONFRILLO, 1994. Price £2.50 plus p.& p.

The Natural History of the Muck Islands, N. Ebudes:

Introduction and Vegetation with a List of Vascular Plants. R.H. DOBSON & R.M. DOBSON, 1985. Price £1.00 plus p. & p.

Seabirds and Wildfowl. R.H. DOBSON & R.M. DOBSON, 1986. Price £1.00 plus p. & p.

Landbirds. R.H. DOBSON, 1988. Price £1.00 plus p. & p.

The following bound reprints from the *Glasgow Naturalist* may be obtained from the librarian at the above address and at the prices shown.

Additions to the Flora of the Clyde Area. John R. Lee (1953). £1 (p.&p.)

Archives

For archive information and special collections of the GNHS contact Karol Magee, Tel. 0141 287 2907.

Society Microscopes

The Society incorporates the Microscopical Society of Glasgow. Microscopes may be borrowed by members and are currently kept in the room of E.G. Hancock, Curator of Entomology, in the Graham Kerr Building, University of Glasgow.

Front Cover

Galls of Knopper gall wasp (*Andricus quercuscalicus*) growing from the cups of acorns on Oak (Quercus robur), Marr Hall Hotel parkland, Erskine, September 2002.

Insert: adult asexual female Knopper Gall wasp (*Andricus quercuscalicus*) February 2003 – x 7.

Photographs © Norman Tait.

Back Cover

Top. Water Fern (*Azolla filiculoides*) South Haugh, Hamilton, September 2003.

Photograph © Peter Macpherson.

Bottom. Japanese Knotweed (*Fallopia japonica* var *japonica*) Millport, Isle of Cumbrae, May 2004.

Photograph © Azra and Peter Meadows.

The Glasgow Naturalist
Volume 24 Part 2 2004

CONTENTS

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 1-4.

THE GLASGOW NATURALIST
EDITORIAL

Azra Meadows and Peter Meadows
DEEB, IBLS, University of Glasgow, G12 8QQ
Emails: <gbza31@udcf.gla.ac.uk> and <gbza21@udcf.gla.ac.uk>

The Glasgow Naturalist journal has a long and distinguished history dating back to the 19th century. It now has a unique and developing role to play in terms of the ecology and biodiversity of terrestrial, freshwater and marine environments in and around Scotland. This includes the following topics, many of which are central issues for Scotland at local, national and international levels.

Biodiversity at all its levels including plants, animals and microorganisms.
Taxonomic descriptions of new and rare species.
Field studies of species and ecosystems.
Experimental studies of species and ecosystems.
Wildlife conservation and management.
Environmental management and impact assessment.
Historical and archaeological aspects of natural history.
Lives and activities of eminent natural historians
Environmental implications of waste management.
Implications of climate change.
Environmental geomorphology.
Environmental engineering.
Eco-sociological issues.
Environmental economics and policy.

Members of the Glasgow Natural History Society, together with our amateur and professional contributors, are essential to the future success of the journal, and to its development as a prestige journal originating from the West of Scotland. As editors, therefore, we hope that the Glasgow Naturalist will provide our contributors and our wider reading audience with a quality service, as follows.

- Production of a journal that is 21st century orientated in its contents and presentation.
- Encouragement of high quality papers on Scottish topics or topics that have relevance to local and national issues in Scotland.
- Stimulation of a broadening of the breadth of subject areas of submitted papers, including all aspects of freshwater, marine and terrestrial ecosystems and species in Scotland.
- Encouragement of younger biologists, whether amateurs or professionals, including postgraduate and undergraduate students, to submit quality research and review articles and short notes.
- Provision of an effective professional standard of refereeing and editing for the journal.
- Provision of leadership for amateur and professional contributors to the journal in relation to subject topic and paper layout for the journal, especially in relation to current electronic facilities.

The Glasgow Naturalist receives papers and short notes on a range of subject areas. After examining the subject areas covered by The Glasgow Naturalist for the last decade we felt it timely to assess what the broad areas and their distribution are. We have reviewed the breadth and statistics of subject areas, which have been covered in the Glasgow Naturalist during 1996 to 2001 (Volume 23 parts 1-6) and during 2002 to 2004 (Volume 24 parts 1-2). We have classified the papers and short notes into four broad subject areas: general, terrestrial, freshwater and marine, whose overall percentages are illustrated in Figure 1. The contents of the current volume (volume 24 part 2) are shown in table 1. Table 2, at the end of this editorial, provides a detailed breakdown for volume 23, parts 1 to 6 which were edited by Roger Downie, and volume 24 parts 1 and 2 which have been edited by ourselves – the current editors. The overall pattern throughout this period has been very similar.
The breakdown of the subject areas of the papers and short notes is interesting. In volume 23 parts 1 to 6, 68% of the papers and short notes were on terrestrial topics, 17% on freshwater topics, 8% on marine topics, and 7% on general topics. In volume 24 parts 1 and 2, In volume 23 parts 1 to 6, 76% of the papers and short notes were on terrestrial topics, 8% on freshwater topics, 12% on marine topics, and 4% on general topics. Summing over both volumes of the journal (volume 23 parts 1 to 6, volume 24 parts 1 and 2), there were 159 (70%) terrestrial papers and short notes, 35 (15%) freshwater papers and short notes, 21 (9%) marine papers and short notes, and 14 (6%) general papers and short notes.
We hope that in future the distribution of papers between terrestrial, freshwater and marine subject areas will become more even. Scotland is recognised globally for its unique freshwater lochs and its magnificent marine coastline, as well as for its dramatic mountain and island scenery. This should be reflected in the journal.

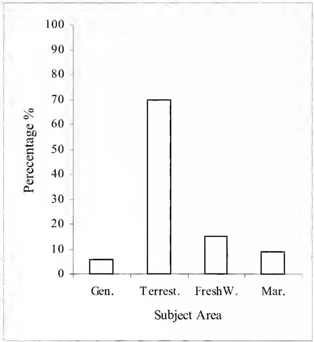


Figure 1. Percentage of subject areas covered in the Glasgow Naturalist volume 23 parts 1 to 6, and in volume 24 parts 1 and 2.

Category	Nos.
Full Papers	17
Short Notes	7
BLB Reports	3
Book Reviews	28
Obituaries	3

Table 1. Current Issue of the Glasgow Naturalist Vol. 24 Part 2 2004.

EDITORIAL PROCEDURE

For contributors who are interested to know the process of editing contributions for a journal, we have listed the following procedure.

1. Paper received in hard copy and electronically from authors. Authors informed of receipt.

2. Initial acceptance or rejection.

2.1 Paper accepted subject to review by referee. Go to **3.**

2.2 Paper rejected. Authors informed.

3. Hard copy of paper sent to referee for review.

4. Hard copy of paper received from referee with comments.

4.1 Referee states that paper is suitable for publication without modification. Go to **8.**

4.2 Referee states that paper is suitable for publication, but needs revision. Go to **5.**

4.3. Referee rejects paper. Authors informed.

5. Hard copy of paper with referee's comments, together with electronic version sent to authors for revision.

6. Hard copy of paper with referee's comments, together with electronic version modified in accordance with referee's comments, received from authors.

7. Editors check that modified electronic version contains all referee's comments.

7.1 Modified electronic version needs further revision, and is returned to authors for further correction.

7.2 Modified electronic version is accepted for publication.

8. Modified electronic version formatted for journal, and sent as hard copy to authors for proof reading. Minor alterations only allowed.

9. Hard copy of authors proofread copy received from authors. Alterations incorporated into formatted electronic version of paper, ready for publication in next issue of the journal.

10. Short notes, Book reviews, BLB reports and obituaries received from collators.

11. Papers, short notes, book reviews, BLB reports, and obituaries collated for next issue of journal, and sent to printers.

12. Final proofs of complete journal issue received by editors from printers, and checked for errors in pagination.

13. Proofs with corrections returned to printers for printing.

14. Print run received from printers. Copies of journal and reprints of papers distributed to members of the Glasgow Natural History Society and authors.

In general, following the submission of a paper, the whole process running from item 1 to 14 takes between 10 and 20 months. This is the time it takes for a paper to be published in any national or international peer-reviewed journal.

CONTENTS OF THE CURRENT ISSUE

In the current issue the flora include micro-organisms, orchids, and the Japanese knotweed, beside other terrestrial plants, while the faunal groups include the flatworm, slow worm, butterflies, moths, beetles and woodlouse, hawfinches, goats, cetaceans, otters and bats. Here we list brief accounts of the full papers followed by short notes in alphabetical author sequence as they appear in this volume. The issue opens with a paper by Bland who reappraises the Watsonian

vice-county distribution of the Scottish Cochyliinae (Lepidoptera), reporting that out of the 47 species resident in Britain 32 have been recorded in Scotland. This is followed by Copley and MacPhee's survey of feral goats on the Oa peninsula, Isle of Islay, where they recorded 400 feral goats. The authors predict an increase in goat population in Oa. Foster describes a beetle species *Hydroporus scalesianus* inhabiting fens new to Scotland. The two laboratory-based papers that follow are by Gibson *et al.*, on the New Zealand flatworm *Arthurdendyus triangulatus*. One paper tests the effect of water content and compactness and the other the effect of temperature on the survival of the flatworm. 30% water by weight was shown to give the optimum survival and the species demonstrated preference to 19°C. We then come to a second pair of longer papers now led by Gulliver and co-workers on the conservation biology of the Irish lady's-tresses orchid, *Spiranthes romanzoffiana*. The first paper deals with the population sizes, grazing, vegetation height and capsule status. The study shows grazing on leaves by slugs and vertebrates and on flowering stems by domestic stock and rabbits. The fact that this species can occur in an underground form for up to six years is interesting, together with the presence of mycorrhiza which is a source of fungal organic carbon. The sister paper by Gulliver *et al.* looks at the establishment of 10 enclosures, their sheep and cattle dung counts and hoof holes, and the frequency of *Juncus articulatus* and *Juncus acutifloris x articulatus*.

Kitchener and Herman examine the rare sightings of the Firth of Forth beluga *Delphinapterus leucas*. They have studied the Turner/Monro skull of a beluga specimen whose whereabouts is unknown. The damaged cranium and the missing teeth are suggestive that this skull is that of the missing Firth of Forth beluga. Klemm's paper discusses climate change and its effect the hydrology of three European rivers, River Spey (Scotland), River Neckar (Germany) and the river Alpenrhine (Switzerland). The paper predicts more flooding in the Spey and consequential runoff and winter seasonality. In the Neckar the winter and spring runoffs are higher than the summer and autumn runoffs. The River Alpenrhine shows four independent seasons, but would change with increase in warming from a snowmelt fed river to a rain-fed river. The paper by Lavery *et al.* investigates the growth rate of Ailsa Craig slow-worm *Anguis fragilis* and its prey preference. The laboratory experiments show that slow-worms grew faster and ate more at temperatures of 27-28°C and showed a decrease in this activity at 18°C. There was no size preference for slugs over a range of 0.5-2.5g. This is followed by Macpherson and Lindsay's record of the 266 floral taxa along a strip in Shettleston, east end of Glasgow, and this included seven plants which were the first record for the vice-county. McCafferty has conducted a spraint, track and prey remain survey to assess the distribution and population status of the otter *Lutra lutra* in the Loch Lomond area. His results show that otters were widespread throughout the loch and that there was an increase in the proportion of tributaries with otters present between the late 1970s and 2002. The paper by Meadows and Meadows demonstrates the effect of fine detrital material and microbial activity on the permeability of intertidal sediments from Ardmore bay in the Clyde estuary. The laboratory experiments show that fine detrital material decreases permeability by about 75%, and that heterotrophic bacteria dramatically decreased sediment permeability by 98% while photosynthetic microbial activity decreased permeability by 38%. In the subsequent paper these authors describe the occurrence and distribution of the Japanese knotweed *Fallopia japonica* on the Isle of Cumbrae, and discuss the length of time the species may have been on the Island. The paper by Mitchell considers the stages in the development of an Ox-bow lake beside the Endrick River. It includes a list of plant species along the waters edge and the newly colonized aquatic plants, and describes the changes in river flow. We then come to a biographical account by Moore and Hancock on Glasgow's little-known Edwardian amateur Carcinologist Alexander Patience, and his scientific contributions. This paper examines Patience's involvement with the Marine Biology Station at Millport and with scientific professionals, and includes a full bibliography of his published works. Tait and Tait describe the spread of the Knopper Gall-wasp *Andricus quercuscalicis* into the Clyde area, together with the complex life cycle this insect undergoes. Vorst reports records of Coleoptera from Islay. This study yields 71 species from varying habitats such as the coastal dunes, river banks, moorland and sheep carrion. 18 of the 71 species have not been recorded in Islay before, and five of the 71 species are new for the Inner Hebrides. The last full paper in this issue is by Zonfrillo and Hancock and is also an Island study, but this time on butterflies from Ailsa Craig, Ayrshire. The authors report 21 species of butterflies. Five of these breed regularly and 12 are sporadic on the island, while the remaining are regarded as doubtful.

Under the short notes section, Collis and Collis report the unusual colour forms of the woodlouse *Porcellio scaber* on the Isle of Mull; Dobson describes an ancient beetle collection which he saved; Hansen records the presence of Large-leaved Avens *Geum macrophyllum* in Mugdock Country Park; Knowler and Mitchell record the presence of the red-necked footman moth *Atolmis rubricollis* in West-central Scotland; Lyth reports hawfinches at Talla Reservoir, Peebleshire, and McNaught observes bats in the West End of Glasgow.

Table 2. Numbers and percentages of full papers and short notes according to their subject area (General, Terrestrial, Freshwater, Marine).

Vol. and Part	Papers/ Short Notes	General	Terrestrial	Freshwater	Marine
Edited by Roger Downie					
Vol. 23 (Parts 1-6)	**Papers**	11	50	14	11
	Short notes	1	72	17	4
	Total (Σ = 180)	12	122	31	15
	%	7%	68%	17%	8%
Edited by Azra Meadows and Peter Meadows					
Vol. 24 (Parts 1-2)	**Papers**	2	18	4	5
	Short notes	0	19	0	1
	Total (Σ = 49)	2	37	4	6
	%	4%	76%	8%	12%
GRAND TOTALS					
Vol. 23 and Vol. 24	**Grand Total (Σ = 229)**	14	159	35	21
	Grand Total %	6%	70%	15%	9%

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 5-10.

THE DISTRIBUTION OF THE COCHYLIINAE (LEPIDOPTERA; TORTRICIDAE) IN SCOTLAND.

K.P.Bland
National Museums of Scotland
Chambers Street
Edinburgh
EH1 1JF

INTRODUCTION

The recent completion of the curation of the tortricoid subfamily Cochyliinae in the collection of the National Museums of Scotland (NMS) is an opportune time for a reappraisal of the Scottish distribution of this group. Thus the following is an attempt at a comprehensive up-to-date account of the Watsonian vice-county distribution of the Scottish Cochyliinae, with the further purpose of making more widely available those records not previously published.

All the 47 species of Cochyliinae resident in Britain are represented in the 3,000 specimens of this subfamily in the NMS collection. Thirty-two species have been recorded from Scotland but the authenticity of two of these species requires confirmation. Scottish specimens of this group are present in the collection amassed by A.B.Balfour, J.W.Bowhill, P.W.Brown, I.C.Christie, J.A.Clark, A.A.Dalglish, A.B.Duncan, D.W.H.Ffennell, D.R.Gifford, R.K.Greville, D.J.Jackson, G.A.T.Jeffs, R.F.Logan, C.W.Mackworth-Praed, D.A.B.Macnicol, R.M.Mere, K.J.Morton, E.C. Pelham-Clinton, T.E.D.Poore, A.Richardson and B.W.Weddell. Additional material has been contributed by K.P.Bland, P.A.Buxton, J.L.Campbell, D.L.Coates, Edinburgh University Biological Society, A.G.Long, R.I.Lorimer, I.H.K.Lyster, E.A.M.MacAlpine, P.Marwick, R.& B.Mearns, J.M.Nelson, M.G.Pennington, G.Petrie, O.W.Richards, T. Rogers and A.R.Waterston.

A comprehensive list of the previously published records of Scottish Lepidoptera is held in the National Museum of Scotland (NMS), Chambers Street, Edinburgh in the "Scottish Insects Record Index" (SIRI). This lists under each species the bibliographic reference and an abbreviated locality, often in the form of the Watsonian vice-county number (Shaw, 1987). SIRI contains some 130 references which include information on the Scottish distribution of the Cochyliinae. These have all been carefully checked back to the original to ensure the accuracy of the distribution data quoted here (Table 1). For completeness the author has also included his own records and all other unpublished records known to him.

Watsonian vice-counties (Table 2) divide Britain up into approximately equal sized areas that people can identify with. Current unitary authority boundaries are based more on areas of equal population and so have little value for wildlife recording. Full details of the addition records are shown below. The earliest record is shown, where multiple records exist. Records accompanied by specimens have in some cases been given priority.

TORTRICIDAE

Cochyliinae

Hysterophora maculosana (Haworth, 1811)
Vc. 72 Grove, Dumfries. 9.vi.1977 A.B.Duncan.
Vc. 88 Killin, Perths. 14.vi.1985 M.R.Young.
Vc. 97 Fort William, Inverness. 26.v.1957 E.C.Pelham-Clinton.
Vc. 98 Port Appin, Argylls. 26.v.1956 E.C.Pelham-Clinton.
Vc. 105 Strath More, W. Ross. 10.vi.1963 E.C.Pelham-Clinton.
Vc. 106 Alcaig, Ross. 18.vi.1988 E.C.Pelham-Clinton.

Phalonidia affinitana (Douglas, 1846)
Vc. 73 Caulkerbush, Kirkcud. Larvae 27.xii.1970 (reared) E.C.Pelham-Clinton.

P. manniana (Fischer von Röslerstamm, 1839)
Vc. 79 Selkirk. 28.vi.1941 B.W.Weddell.
Vc. 82 Tyninghame, E. Loth. 5.vi.1933 A.B.Balfour. The specimen is very worn and without an abdomen and so is unidentifiable. It bears an identification label "*Phalonia manniana* FR." in Alice Balfour's handwriting.

Gynnidomorpha minimana (Caradja, 1916)
Vc. 80 Whitlaw Moss, Roxburgh. 3.vii.1981 K.P.Bland - erroneously published as in Vc.79. No records from Vc.79 are known to me.

G. permixtana ([Denis & Schiffermüller], 1775)
Vc. 98 At the 1957 Annual Exhibition of the South London Entomological Society, Pelham-Clinton (1958) exhibited specimens of *Phalonia walsinghamana* Pierce (= *G. minimana*) from Port Appin. This record was repeated by Bradley, Tremewan and Smith (1973). The identity of these specimens was corrected to G. *permixtana* (Pelham-Clinton, 1982).

G.vectisana (Humphreys & Westwood, 1845)
Vc. 73 Auchencairn, Kirkcud. 2003 E.A.M. MacAlpine.

Cochylimorpha alternana (Stephens, 1834)
Vc. 92 There are 3 specimens labelled "Aberdeen" in the J.A.Clark collection which was received in 1906. This is a surprising record and the number and condition of the specimens suggests they may have been mislabelled.

C. straminea (Haworth, 1811)
Vc. 73 Merse Head, Kirkcud. 20.vii.1996 J.MacKay.
Vc. 84 Queensferry, W. Loth. Pre 1857 R.K.Greville.
Vc. 96 Kincraig. 5.vii.1950 P.Harwood (Macnicol coll.).
Vc. 97 Spean Bridge, Inverness. 30.vi.1965 E.C.Pelham-Clinton.
Vc. 105 Kishorn, W.Ross. 18.vii.1984 P.W.Brown.

Agapeta hamana (Linnaeus, 1758)
Vc. 72 Connansknowe, Dumfries. 26.vi.1998 R.Mearns.
Vc. 79 Midgehope Marsh, Selkirks. 3/4.viii.1979 K.P.Bland.
Vc. 84 Winchburgh, W. Loth. 2.viii.1969 E.C.Pelham-Clinton.
Vc. 95 Garten Railway Line, Elgins. 14.vi.1975 M.R.Young.
Vc. 96 Newtonmore Golf Course, E. Inverness, 1.vii.1992 M.R.Young.
Vc. 97 Kilchoan, Ardnamurchan. 28.vi.1965 E.C.Pelham-Clinton.
Vc. 105 Kishorn, W.Ross. 1.vii.1985 P.W.Brown.
A. zoegana (Linnaeus, 1767)
Vc. 72 Castlehill, Dumfries. 7.viii.1973 A.B.Duncan.
Vc. 73 Kirkconnell, Kirkcud. 31.vii.1977 A.B.Duncan.
Vc. 83 Burdiehouse, Midloth. 7.vii.1958 D.A.B.Macnicol.
Vc. 84 Winchburgh, W.Loth. 11.viii. 1965 E.C.Pelham-Clinton.
Vc. 90 Lunan Bay, Angus. 7.viii.1996 B.Goater.
Aethes cnicana (Westwood, 1854)
Vc. 73 Lochaber Loch, Kirkcud. 2.vii.1996 J.MacKay.
Vc. 75 Kennedy's Pass, Ayrshire 19.vii.1984 I.C.Christie.
Vc. 78 Menzion Farm, Tweedsmuir. 23/24.vii.1979 K.P.Bland.
Vc. 79 Thornielee, Selkirks. 19.vi.1981 A.Buckham
Vc. 85 Tayport, Fife. 4.vii.1970 E.C.Pelham-Clinton.
Vc. 89 Glenshee, Perths. 1976 E.F.Hancock.
Vc. 96 Rothiemurchus. vii.1896 K.J.Morton.
Vc. 98 Inverlochy, Argylls. 26.vi.1943 C.W.MacKworth-Praed.
Vc. 100 Shiskine, Isle of Arran. 26.vi.1999 M.R.Young.
Vc. 101 Tayvallich, Kintyre. 5.vii.1974 E.C.Pelham-Clinton.
Vc. 102 Colonsay. Date unknown. T.C.Dunn.
Vc. 105 Rassal, W. Ross. 25.vi.1991 P.W.Brown.
Vc. 106 Swordale, E. Ross. 11.vii.1909 D.J.Jackson.
Vc. 110 Isle of Lewis. 1901 H.McArthur (Mackworth-Praed coll.).
A. piercei Obraztsov, 1952
Vc. 73 Balmae, Kirkcud. 18.vi.1999 J.MacKay.
Vc. 74 Stranraer,Wigtown. 22.vi.1998 R.Mearns.
Vc. 75 Bennane Head, Ayrshire. 4.vi.1987 I.C. Christie.
Vc. 82 Petersmuir, E.Loth. 28.vi.1935 A.B.Balfour.
Vc. 84 Queensferry, W. Loth. pre 1857 R.K.Greville.
Vc. 88 Kinloch Rannoch, Perths. v.1927 T.E.D.Poore.
Vc. 96 Speybridge, Inverness. 9.vi.1968 E.C.Pelham-Clinton.
Vc. 97 Arisaig, Westerness. 2.vi.1941 C.W.Mackworth-Praed.
Vc. 101 Tayvallich, Kintyre. 12.vi.1981 I.C.Christie.
Vc. 105 Kishorn, W.Ross. 6.vi.1988 P.W.Brown.
Vc. 106 Swordale, E. Ross. 20.vi.1908 D.J.Jackson.
A. rubigana (Treitschke, 1830)
Vc. 72 Parkgate, Dumfries. 9.vii.1982 E.C.Pelham-Clinton.
Vc. 73 Kirkdale, Kirkcud. 10.vii.1999 R. & B.Mearns.
Vc. 79 Glen Kinnon, Selkirks. 31.vii.1999 A.Buckham.
Vc. 81 Gordon, Berwicks. 18.vii.1953 E.C.Pelham-Clinton.
Vc. 84 Winchburgh, W. Loth. 8.vii.1970 E.C.Pelham-Clinton.
Vc. 85 Aberdour, Fife. 27.vii.1969 E.C.Pelham-Clinton.
Vc. 89 Kinnaird, Perths. 2/4.vii.2000 J.A.T.Woodford.
Vc. 90 The Scorrie, Glen Clova. 14.vii.1995 K.P.Bland.
Vc.104 Isle of Canna. 29.vii.1971 J.L.Campbell.
Vc.106 Nigg Sutor, E. Ross. 9.vii.1910 D.J.Jackson.
A. smeathmanniana (Fabricius, 1781)
Vc. 72 Kirkton, Dumfries. 7.vii.1996 R. Mearns.
Vc. 73 Merse Head, Kirkcud. 20.vii.1996 J.MacKay.
Commophila aeneana (Hübner, 1800)
Vc. 92 There are 2 specimens labelled "Aberdeen, 1910 Purdey coll." In British Museum (Natural History) (Bradley, Tremewan & Smith, 1973). This is a surprising record that has never been repeated. A single specimen was taken on a window in Berwick-on-Tweed (Vc.68) in 1887 (Bolam, 1929) suggesting that it is an occasional vagrant.
Eupoecilia angustana (Hübner, 1799)
Vc . 72 Kettleton, Dumfries. 13.vii.1978 A.B.Duncan.
Vc. 73 Kirkconnell, Kirkcud. 4.viii.1976 A.B.Duncan.
Vc. 78 Whim Moss, Peebles. 12.viii.1986 K.P.Bland.
Vc. 79 Selkirk. 16.vi.1943 B.W.Weddell.
Vc. 84 Winchburgh, W. Loth. 20.vii.1979 E.C.Pelham-Clinton.
Vc. 94 Cullykhan, Banff. 22.vii.1993 M.R.Young.
Vc. 97 Arisaig Islands. 7.vi.1941 C.W.Mackworth-Praed.
Vc.101 Taynish, Kintyre. 11.vi.1983 K.P.Bland.
Vc.105 Beinn Eighe, W. Ross. 1953 O.W.Richards.
Vc.107 East Sutherland. Date unknown. H.N.Michaelis.
E. ambiguella (Hübner, 1796)
Vc. 83 Logan (in Lowe & Logan, 1852) reported a possible specimen of *Eupœcilia ambiguana* Steph. from Duddingston (Vc. 83), but later corrected its identity to *E. atricapitana* St. (Logan,

1853). Wilkinson (1859) presumably overlooked this correction and states that *E. ambiguella* "has also occurred near Edinburgh".

Cochylidia subroseana (Haworth, 1811)

Pre 1895 Scottish records of *Eupœcilia subroseana* refer to the richly coloured form of *Falseuncaria ruficiliana* (see White, 1869; Barrett, 1869; Griffith, 1884; and Bankes, 1893).

C. implicitana (Wocke, 1856)

Vc. 73 Barlocco Bay, Kirkcud. 6/7.viii.2003 R.& B.Mearns.

C. rupicola (Curtis, 1834)

Vc. 73 Abbeyburnfoot, Kirkcud. 22.vi.1996 R.Mearns.

Falseuncaria ruficiliana (Haworth, 1811)

Vc. 73 Hannaston Wood, Kirkcud. 22.vi.1996 K.P.Bland.

Vc. 95 Aviemore. 12-21.vi.1909 E.R.Bankes (Brit.Mus.(Nat.Hist.) coll.).

Vc 96 Aviemore area, Easterness. 17.vi.1967 E.C.Pelham-Clinton.

Vc. 97 Lochailort, Westerness. 4.vi.1941 C.W.Mackworth-Praed.

Vc. 101 Ronachan, Kintyre. 10.v.1953 E.C.Pelham-Clinton.

Vc. 102 Colonsay. Date unknown. T.C.Dunn.

Vc.105 Kishorn, W. Ross. 25.vi.1980 P.W.Brown.

Vc. 107 Invershin, Suth. 19.v.1921 F.G.Whittle (Brit.Mus.(Nat.Hist.) coll.).

Cochylis atricapitana (Stephens, 1852)

Vc. 73 Carsfad, Dalry, Kirkcud. 4.vi.1993 J.MacKay.

Vc. 74 Tors, Wigtown. 13.viii.1983 A.B.Duncan.

Vc. 75 Ailsa Craig, Ayrshire. 21.v.1983 I.C.Christie.

Vc. 76 Paisley, Renfrews. 12.v.1983 J.Morgan.

Vc. 81 Gordon, Berwicks. 14.vi.1952 E.C.Pelham-Clinton.

Vc. 84 Winchburgh, W. Loth. 4.vi.1964 E.C.Pelham-Clinton.

Vc. 89 Aldclune Meadow, Perths. 19.vi.1988 K.P.Bland.

Vc. 90 The Strone, Glen Clova. Larvae. 4.viii.1992 (reared) K.P.Bland.

Vc. 95 Aviemore. 23.vi.1908 E.R.Bankes (Brit.Mus.(Nat.Hist.) coll.).

Vc. 97 Sanna, Ardnamurchan. 6.viii.1956 E.C.Pelham-Clinton.

Vc. 98 Benderloch, Argylls. 15.vi.1974 E.C.Pelham-Clinton.

Vc. 101 Southend, Kintyre. 2.vi.1985 I.C.Christie.

Vc. 103 Carsaig, Mull. 14.vi.1989 I.C.Christie.

Vc. 105 Wester Ross. Date unknown. J.M.Chalmers-Hunt.

C. nana (Haworth, 1811)

Vc. 73 Beeswing. 1980 E.F.Hancock.

Vc. 79 Selkirk. 1.vii.1931 B.W.Weddell.

Vc. 81 Gordon, Berwicks. 30.vi.1951 E.C.Pelham-Clinton.

Vc. 84 Blackburn, W. Loth. 9.vi.1970 E.C.Pelham-Clinton.

Vc. 85 Markinch, Fife. 1.vi.1980 E.C.Pelham-Clinton.

Vc. 89 Glen Garry, Perths. 22.vi.1975 E.C.Pelham-Clinton.

Vc. 97 Lochailort, Westerness. 15.vi.1941 C.W.Mackworth-Praed.

Vc. 98 Lephinmore, Argylls. 20.v.1952 E.C.Pelham-Clinton.

Vc.101 Taynish, Kintyre. 14.vi.1985 I.C.Christie.

Vc.105 Kishorn, W. Ross. 26.vi.1985 P.W.Brown.

Vc.107 Shin Falls, Suth. 2/3.vi.1990 K.P.Bland.

C. pallidana Zeller, 1847

Vc. 73 Portling, Kirkcud. 7.vi.1984 A.B.Duncan.

C. roseana (Haworth, 1811)

G.H.Stainton (1845) reported this species from Airthrey (Vc.86). The record seems most unlikely and H.T. Stainton seems to have realised the error, for the record is under *E. subroseana* (=*Falseuncaria ruficiliana*) in the manual (Stainton, 1859).

It is hoped that entomologists will in future keep this distribution data up-to-date by publishing, or communicating to the author, any new vice-county records they have or get.

ACKNOWLEDGEMENTS

The author is very grateful to the many fellow entomologists who have kindly made their records available to him.

REFERENCES

Bankes, E.R. (1893) *Eupoecilia subroseana*: a query! *Entomologist's Record* **4** (4), 99-100.

Barrett, C.G. (1869) Notes on some British species of *Eupoecilia*. *Entomologist's Monthly Magazine* **5**, 244-246.

Bolam, G. (1929) Lepidoptera of Northumberland and the Eastern Borders. *History of the Berwickshire Naturalists' Club* **27**, 115-142.

Bradley, J.D., Tremewan, W.G. & Smith, A. (1973) *British Tortricoid Moths. Cochylidae and Tortricidae: Tortricinae.* Ray Society, London. viii+ 251 pp.

Dandy, J.E. (1969) *Watsonian Vice-counties of Great Britain*. Ray Society, London.33pp + 2 maps.

Griffith, A.F. (1884) Tortrices, &c., in South Wales and Sutherlandshire. *Entomologist's Monthly Magazine* **20**, 259-260.

Logan, R.F. (1853) Additions to the Lepidoptera of Midlothian. *The Naturalist (B.R. Morris edit.)* **3**, 69-71.

Lowe, W.H. & Logan, R.F. (1852) The Lepidopterous Insects of Midlothian. *The Naturalist (B.R. Morris edit.)* **2**, 141-149.

[Pelham-Clinton, E.C.] (1958) The Annual Exhibition - Records of Exhibits. 26th October 1957. *Proceedings and Transactions of the South London Entomological and Natural History Society* **1957**, 36-37.

Pelham-Clinton, E.C. (1982) Correction to published records of *Phalonidia minimana* (Caradja)(Lepidoptera: Cochylidae). *Entomologist's Gazette* **33**(2), 121.

Shaw, M.R. (1987) Scottish Insect Records. *Entomologist's Record* **99**, 37-38.

Stainton, G.H. (1845) Capture of Lepidopterous Insects in Scotland in 1845. *The Zoologist* **3**, 1090-1091.

Stainton, H.T. (1859) *A Manual of British Butterflies and Moths*. Vol.2. John van Voorst, London. xi + 480pp.

White, F.Buchanan (1869) Notes on the Lepidoptera inhabiting Rosshire. *Entomologist's Monthly Magazine* **5**, 281-285.

Wilkinson, S.J. (1859) *The British Tortrices*. John van Voorst, London. viii + 328pp.

Table 1. The known Watsonian vice-county distribution of the species of the subfamily Cochyliinae (Tortricidae) in Scotland.

Log Book no.	Species	Scottish Vice County																			
		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
	PHTHEOCHROA																				
921	inopiana (Haw.)					s	s														
	HYSTEROPHORA																				
924	maculosana (Haw.)	**A**	s	s	**S**	s	s						s			**S**	s	a			s
	PHALONIDIA																				
932	affinitana (Douglas)		**A**																		
926	manniana (F.v.R.)								**A**			**A?**			s			s			
	GYNNIDOMORPHA																				
930	alismana (Rag.)					**S**	s														
927	minimana (Carad.)			**S**						**A**											
928	permixtana (D. & S.)					s											s				
929	vectisana (H.&W.)	s	a																		
	COCHYLIMORPHA																				
935	alternana (Steph.)																				
936	straminea (Haw.)	s	a	**S**	s	**S**	**S**			s	**S**	**S**	**S**	**A**	s	s	s	**S**	**S**		s
	AGAPETA																				
937	hamana (Linn.)	**A**	s	**S**	s	s	s		a	s	s	**S**	**S**	**A**	s	s	s	s	s		s
938	zoegana (Linn.)	**A**	**A**	**S**	s					s	s	**S**	**A**	**A**	**S**	s	s	**S**	s	a	**S**
	AETHES																				
945	cnicana (Westw.)		a	s	a	s	**S**	a	a	s	**S**	**S**	**S**	**S**	**A**	**S**	s	**S**	a	s	s
950	francillana (F.)									s											
941	hartmanniana (Cl.)												s	s							
942	piercei Obraz.	s	a	**A**	**A**	s	**S**			s	**S**	**A**	**S**	**A**		s		**A**	s		s
946	rubigana (Treits.)	a	a			s	s		a	s	**A**	**S**	**S**	**A**	**A**	**S**	s	s	a	a	s
940	rutilana (Hb.)									s											
947	smeathmanniana (F.)	a	a		s	s	**S**						s		**S**			s			s
939	tesserana (D. & S.)					s															
	COMMOPHILA																				
952	aenaena (Hb.)																				
	EUPOECILIA																				
954	angustana (Hb.)	**A**	**A**	**S**	**S**	**S**	**S**	a	**A**	s	**S**	**S**	**S**	**A**	**S**	**S**	**S**	**S**	**S**	s	**S**
955	ambiguella (Hb.)												s?								
	COCHYLIDIA																				
956	implicitana (Wocke)		a	s																	
959	rupicola (Curtis)		**A**																		s
	FALSEUNCARIA																				
960	ruficiliana (Haw.)		a			s	**S**			s	s	**S**	**S**		s	s	s	**S**	**S**		
	COCHYLIS																				
966	atricapitana (Steph.)		a	**A**	**A**	a				s	**A**	**S**	**S**	**A**	**S**		s	s	a	a	s
964	dubitana (Hb.)				s	**S**	s				s	s	**S**		s			s			
965	hybridella (Hb.)									s	s	s	s								
968	nana (Haw.)	s	a			s			**A**		**A**	**S**	**S**	**A**	**A**	**S**	**S**	**S**	**A**	s	s
967	pallidana Zell.		**A**		**S**		s														
962	roseana (Haw.)															s?					

Log Book no.	Species	Scottish Vice County																				
		92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
	PHTHEOCHROA																					
921	inopiana (Haw.)								s													
	HYSTEROPHORA																					
924	maculosana (Haw.)	s	s				**A**	**A**	s		**S**		s		**A**	**A**	s					
	PHALONIDIA																					
932	affinitana (Douglas)									s												
926	manniana (F.v.R.)																					
	GYNNIDOMORPHA																					
930	alismana (Rag.)								s													
927	minimana (Carad.)																					
928	permixtana (D. & S.)							**S**	s	s												
929	vectisana (H.&W.)																					
	COCHYLIMORPHA																					
935	alternana (Steph.)	**A?**																		s		
936	straminea (Haw.)	s	s			**A**	a	**S**	**S**	s		s	**S**	s	**A**			**S**		**S**		
	AGAPETA																					
937	hamana (Linn.)	s		a	a	a	**A**	**S**	**S**	s		s	**S**	**S**	**A**			**S**		s	s	
938	zoegana (Linn.)																					
	AETHES																					
945	cnicana (Westw.)	s	s	s	**S**	**A**		**A**	**S**	a	a	a	**S**	s	**A**	**A**	s			**A**	**S**	**S**
950	francillana (F.)																					
941	hartmanniana (Cl.)							s	s					s		s				s	s	
942	piercei Obraz.	s	s		s	**A**	**A**	**S**	s		**A**		**S**	s	**A**	**A**		**S**		**S**	**S**	
946	rubigana (Treits.)	s	s					**S**	s			s		**A**		**A**				**S**		s
940	rutilana (Hb.)														s							
947	smeathmanniana (F.)	s	s	s		s			**S**					s	**S**							**S**
939	tesserana (D. & S.)							s		s												
	COMMOPHILA																					
952	aenaena (Hb.)	s?																				
	EUPOECILIA																					
954	angustana (Hb.)	s	s	a	**S**	**S**	**A**	**S**	**S**	**S**	a	s	s	s	**A**	**S**	a	**S**	s	**S**	**S**	s
955	ambiguella (Hb.)																					
	COCHYLIDIA																					
956	implicitana (Wocke)																					
959	rupicola (Curtis)						**S**				**S**								s			
	FALSEUNCARIA																					
960	ruficiliana (Haw.)	s			a	**A**	**A**	**S**	s		**A**	a	**S**	s	**A**	**S**		**S**		**S**	**S**	**S**
	COCHYLIS																					
966	atricapitana (Steph.)	**S**	s		a	**S**	a	a	**S**		**A**		**A**		a				**S**	**S**		
964	dubitana (Hb.)																					s
965	hybridella (Hb.)																					
968	nana (Haw.)	s	s		s	**S**	**A**	**A**	**S**	**S**	**A**	s			**A**		a					
967	pallidana Zell.																					
962	roseana (Haw.)																					

S or s – Published records quoted in SIRI.
A or a – Additional records not in SIRI, i.e. currently unpublished.
Letters in **bold** capital script indicate specimen of this provenance is present in NMS.

Table 2. Watsonian vice-counties for Scotland.

Vc Number	Vice County	Vc Number	Vice County
72	Dumfriesshire	93	North Aberdeenshire
73	Kirkcudbrightshire	94	Banffshire
74	Wigtownshire	95	Moray
75	Ayrshire	96	East Inverness-shire (with Nairn)
76	Renfrewshire	97	West Inverness-shire
77	Lanarkshire	98	Argyll Main
78	Peebleshire	99	Dumbartonshire
79	Selkirkshire	100	Clyde Isles
80	Roxburghshire	101	Kintyre
81	Berwickshire	102	South Ebudes
82	East Lothian	103	Mid Ebudes
83	Midlothian	104	North Ebudes
84	West Lothian	105	West Ross
85	Fife & Kinross	106	East Ross
86	Stirlingshire	107	East Sutherland
87	West Perthshire (with Clackmannan)	108	West Sutherland
88	Mid Perthshire	109	Caithness
89	North Perthshire	110	Outer Hebrides
90	Angus (& Forfar)	111	Orkney Islands
91	Kincardineshire	112	Shetland Islands
92	South Aberdeenshire		

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 11-20.

A SURVEY OF FERAL GOATS ON THE OA PENINSULA, ISLE OF ISLAY, WESTERN ISLES, SCOTLAND, JULY 2003

Peter B. Copley[1] and Donald James MacPhee[2]

[1] Biodiversity Conservation Programs, South Australian Department for Environment and Heritage, GPO Box 1047, Adelaide, S 5001, Australia.
E-mail: copley.peter@saugov.sa.gov.au

[2] Author to whom enquiries should be directed: Dunlossit Garden Cottage, Port Askaig, Isle of Islay, Argyll, PA46 7RE, United Kingdom; E-mail: macphee-islay@supanet.com

ABSTRACT

An observational survey of feral goats was conducted on The Oa peninsula of the Isle of Islay, Scotland, between 6th and 17th July 2003. Approximately 400 (+/- ca30-40) goats were recorded in 45 groups varying in size from 1 to 44 individuals. Most groups were recorded within less than 500 metres of the coast where they regularly found shelter amongst rock-falls and in various caves in the cliffs. White, black and brown were the most frequently recorded coat colours, followed by a combination of white/beige. Horn characteristics of adult billies, evidence of tagged individuals, and accounts of local farmers, suggest that this goat population has arisen from several sources on several occasions.

The total number of goats recorded during this survey is similar to a count obtained in 2000, but considerably larger than all previous counts obtained for the area between 1981 and 1998. Despite an annual cull of between 40 and 50 goats being conducted for landholders on the northern half of The Oa since 1997, the population still appears to be increasing.

This paper provides a relatively detailed baseline against which future systematic counts of goats on The Oa may be compared.

INTRODUCTION

Feral goats, *Capra hircus*, originating from local domestic animals, have been established along the coastal cliffs and adjacent moors and grasslands of the Scottish island of Islay for at least a century, and probably for considerably longer. These goats occur in four discrete areas of the island. The largest sub-population is on The Oa peninsula (locally referred to as "The Oa") at the island's southern extremity. The next largest is on the north-eastern portion of the island, east and north-east of Gortantaoid Point and mostly north-west of Bunnahabhain. Another occurs on the Rhinns of Islay – the island's south-western peninsula. A fourth small sub-population occurs in the Smaull Farm to Sanaigmore (to Ardnave Point) area on the north-western corner of the island. In addition, a population of feral goats occurs on the small island of Texa that lies about 600m off the south coast of Islay and 4km to the east of the Oa peninsula.

Following the recent acquisition of Kinnabus Farms to add to it's other reserve holding of Upper Killeyan Farm on The Oa peninsula, the Royal Society for the Protection of Birds (RSPB) had gained ownership and management responsibility for approximately the south-western half of the peninsula. The Oa Reserve has been established primarily for the conservation of choughs, *Pyrrhocorax pyrrhocorax*, which have their largest breeding population in Britain here on the Isle of Islay.

The survey described below was undertaken to determine the current distribution and relative abundance of feral goats on The Oa, as a basis for determining future management requirements and options on this newly enlarged, 1,883 hectare reserve. Information was also sought to determine current distribution and abundance of goats on other parts of Islay and on the nearby island of Texa.

METHODS

The survey area

The Isle of Islay (lat. 55^0 45' 20" N; long. 06^0 15' 20" W) is the most southerly of the Western Hebridean Isles of Scotland and lies approximately 23km west of the Scottish mainland (see Fig. 1). It is a large island, measuring approximately 40 km from north-to-south and 30 km from east-to-west, but is almost dissected, as shown in Fig. 1, along its north-south axis by Loch Gruinart from the north and the wider intrusion of Loch Indaal and Laggan Bay from the south.

Islay experiences an Atlantic seaboard climate described as "hyperoceanic, humid, temperate - 01 H3 T1" (see MacKay, 1996). Figure 2 plots mean monthly rainfall and mean monthly maximum temperatures, as recorded at the meteorological recording station on Islay between 1983 and 1987 - the recording station closed at the end of 1987. Mean annual rainfall for the period was 1,043 mm (range 975-1103mm) over the five-year period. The months from September - January tend to receive more rain than the other months, but the pattern is very variable. Temperatures are lowest between November and March, although the pattern for this is also variable. Sea fog often obscures visibility at altitudes above about 100m even during summer months (including on one day during this survey). The high sea-cliffs rising 1-200m above sea level add a significant level of wind-chill to minimum temperatures. Winter gales are common, with strong winds predominantly from the SW quarter.

The Oa peninsula is the oval-shaped, southern-most promontory of the Isle of Islay and is situated immediately to the west and south-west of the town

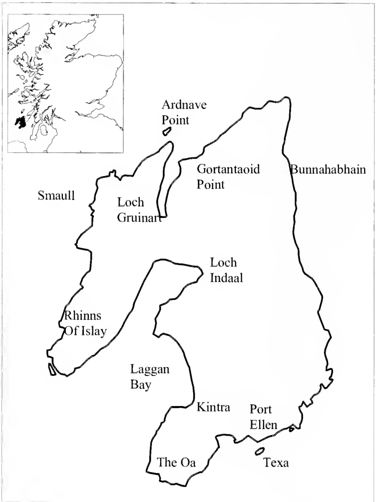


Figure 1. Map of the Isle of Islay, with inset showing location relative to the Scottish mainland

of Port Ellen (Fig. 3). It measures nearly 8km east-to-west, 8.5km north-to-south, covers approximately 47 km^2, and has a ('smoothed') coastal circumference of ca 26km. The Oa is mostly a gently undulating, hilly landscape with the highest point, Beinn Mhor, rising to 202m. It is covered mostly by heather moorland and improved and semi-improved pasture, and fringed by coastal cliffs, steep grassy slopes and numerous rocky coves (see Ordnance Survey "Pathfinder" map 439 (NR 24/34/44) "Port Ellen" for details). The Oa reserve consists of approximately 800ha of dry heath / acid grassland (42%), 650ha of coastal grassland / heath (35%), 350ha blanket bog (19%), 65ha of improved grassland (3%), 5ha of arable land and 13ha of standing water (RSPB, unpublished report 2002; but see also Madders, et al. 1998). Scattered around the coastline are many caves of varying dimensions, mostly former sea-caves with entrances at, or near, the cliff-base and indicative of former relatively higher mean sea levels.

The Oa reserve has been used for grazing of mixed, traditional suckler-type cows and of Highland black-faced sheep. Such grazing will be retained by RSPB to maintain and improve the grassy pastures as feeding habitats for chough (see Madders, et al. 1998; Finney and Jardine 2003) and other farmland birds of conservation concern. However, numbers of both sheep and cattle have been reduced significantly on The Oa in recent years and future management may require changes in grazing regimes (grazing species, density, frequency, timing) in key management zones to achieve particular conservation outcomes. The role that grazing and browsing by feral goats may play in this is yet to be determined.

Survey Methods

The coastal perimeter of The Oa peninsula was surveyed on foot, searching for individuals or groups of feral goats both on the cliff-slopes and inland. High vantage points with clear views over large areas were sought first to note the positions of distant groups and how best to approach these. Visibility was generally very good for locating goats, due to the vast areas of very low vegetation and the starkly contrasting colours of the goats' pelage. The significant exceptions to the good visibility were numerous, mostly fairly small, areas obscured by topographic features such as ridges and gullies. These were searched fairly systematically, although some small areas were inevitably missed. Also, a few areas of tall bracken were searched carefully as small numbers of goats were occasionally hidden within them. One of us (DJM) is familiar with these areas of cover often used by goats on The Oa, and has regularly stalked and culled small numbers of goats there for the local farmers and for occasional trophy hunters.

When goats were located, an initial count was obtained. Then group composition, based on the numbers of adult males (billies), adult females (nannies) and kids was recorded, with 'yearling' and younger kids separated where possible. Where distant groups disappeared from sight before all group characteristics could be recorded, total counts were obtained as a priority and then numbers of 'obvious' adult males were noted. The composition of a small number of groups was therefore insufficiently known and a minimum number of adult males were recorded. These groups are marked with an asterisk in the summary table (Appendix 1). In these situations all other goats were recorded as "adult females +/- kids". Consequently, the numbers of adult males is likely to be a slight under-estimate and the numbers of adult females +/- kids a slight over-estimate.

An attempt was also made to identify particular groups based on coat colours and coat patterns, and on the size and shape of the horns of particular adult males. No attempt was made to classify the age of individual goats based on horn ring counts (after Bullock and Pickering 1984). This would have

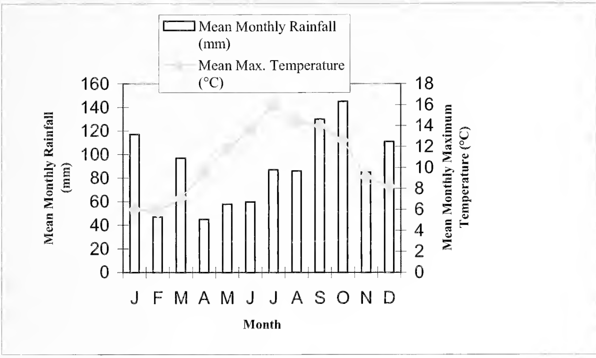


Figure 2. Climatic conditions. Isle of Islay.

required far longer than time permitted for this general overview survey.

Coat colours recorded were simplified to black (B), white (W), brown (Br) and beige (Be), and predominant combinations of these (e.g. B/Br, B/W, etc.). Although scoring of these colours and combinations was, at least in part, subjective, it nevertheless provided a useful cue for recognition of particular groups.

The whole survey was conducted from 6th to 17th July 2003. One or two people with binoculars and a telescope, and two to four other observers, walked close together at all times, except when goats needed to be 'flushed' from cover back in the direction of the main recorder(s). The weather was clear on all but one foggy day when only a short stretch of coastline around Glen Astle was searched. Wherever possible, searching was carried out into the wind, so that goats could be approached as closely as possible.

On the evening of 16 July, four people conducted a survey of the feral goats on the uninhabited isle of Texa. The goats have been present on this low, hillocky island of approximately 60ha for many decades. The numerous hillocks and, in some places, tall bracken, obscured visibility of several areas of the island, especially in the north. But the hillocks also provided excellent vantage points for observing goats once they were located and 'driven' into open areas. A find-flush-and-count method was therefore used for this survey.

Approximate numbers of goats present in other areas of Islay were obtained from knowledgeable local residents, to provide as complete a view of feral goat numbers and distribution across the island contemporaneous with that obtained in this more detailed survey on The Oa.

RESULTS

The locations, relative sizes and composition of groups of feral goats encountered during this survey on The Oa are shown in Figure 4. From this it is clear that the goats occur predominantly along the coast and for only short distances (up to 1km) inland. It is also evident from this plot that the groups are clumped in particular areas.

Minimum numbers of goats observed, by sex and by relative age (young kids up to about 4 months old, 'one-year-old' kids actually about 6-8 months old, and adult females and adult males) are summarised per group recorded in Appendix 1.

A total of 432 goats were recorded in 46 groups, although one of these groups of 12 individuals was definitely seen and scored twice. Thus a maximum of 420 goats were observed in 45 groups. These groups included:

- at least 166 billies within 27 groups,
- a maximum of 204 nannies within 34 groups,
- at least 49 "year-old" kids within 28 groups
- only three young kids within three separate groups.

Group size (see Fig. 5) ranged from one to 44 individuals (mean 9.8 goats; n=45). Twenty-three percent of groups were all-male groups and ranged in size from three to 11 individuals (mean 6.0; n=10). Thirty-five percent of groups were female +/- kid groups and ranged in size from one to 23 individuals (mean 5.1; n=16). Forty-two percent of groups were mixed sex groups, ranging in size from five to 44 individuals (mean 15.8; n=19).

Interpretation of data

The number of adult females recorded was greater than for adult males (0.55:0.45), although there was almost certainly an over-count of females and a corresponding under-count of males, due to the rapidity with which three groups disappeared from sight and the consequent method used to record group composition. When these groups are removed from this part of the analysis, the sex ratio becomes 0.48:0.52.

As the counts in the present survey were performed over several days and there appeared to be some fluidity between groups (e.g. some groups divided or amalgamated as they grazed or as they returned to their shelter sites late in the day), the count data presented are likely to include some 'double-counting' of individuals. This is most likely to have occurred within the area between Dun Athad, just east of The Mull of Oa, and Stremnishmore, because different counts were made along partially-overlapping areas of this section on at least three separate days, over an eight day period. However, it is thought that this is unlikely to represent more than about 30 to 40 individuals of the 60 counted in this area on 7th July (see Appendix 1). In addition, a group of 12 is also known to have been counted twice between The Mull of Oa and Lower Killeyan (as already mentioned), but this has been accounted for in the total.

Any double-counting is also likely to be countered by the possible lack of sighting of a group of 40-60 goats that are considered by one of us (DJM), and by Hamish McTaggart the owner of Kintra Farm (pers. comm.), to be 'resident' on Kintra Farm. On the day that Kintra Farm was surveyed, and also on the day before, the property had been quartered on quad bikes to find and muster all sheep for their annual wool clip. As a consequence of this, the local group(s) of goats may have moved elsewhere, and only eight goats were seen on this property despite considerable search effort. Numbers seen immediately to the south of here were not particularly high, and were not higher than might have been expected from local accounts.

The coat colours and patterns of the goats were many and varied and careful noting of these would greatly enhance future identification of individuals, or at least some individuals within particular groups or areas. While the scoring of coat colours in this survey was simplified to either predominant colour or a combination of the two predominant colours, this was still a useful practice for attempting to distinguish groups, especially when combined with each animal's sex. The relative frequencies of predominant coat colours by sex are summarised in Fig. 6. White is the most frequent coat colour among both male and female goats on The Oa. Black coat colour and brown were next most frequently recorded, followed by the combinations of white/beige and black/brown. A few individuals also had very distinctive coat patterns such as square patches or circular 'bulls-eyes' that allowed them to be identified immediately.

Mature male goats on The Oa exhibit a variety of horn shapes. Many have the relatively simple, backward-curving, scimitar-type of horn. Others have an additional outwards curve, while still others curve, or flair, outwards at least twice, with some spiralling of the horns. These characteristics add considerably to the observer's ability to identify individual animals.

b) Comparison of counts of feral goats on The Oa with other areas on Islay

Table 1 below summarises counts, or recent estimates, of feral goat numbers on other parts of Islay, and on the isle of Texa. It also compares the current survey counts with those of previous counts conducted on The Oa.

While the current survey is almost certainly the most thorough undertaken on The Oa, it is worth noting the much higher numbers recorded in this area over the last decade. Also of note are the lower counts on The Oa in 1985, indicating either a population decline following the earlier 1980s counts, or the difficulty of locating all goats along this complex coastal landscape.

(c) The Isle of Texa

A total of 84 goats were counted on the isle of Texa during this survey. They were all in a single large tribe consisting of 41 adult males, 32 adult females and 11 kids.

DISCUSSION

a) The Oa Peninsula

Population size and group composition

In July 2003 there were approximately 400 (+/- ca 30-40) feral goats living on The Oa peninsula of Islay. This total is very similar to that obtained by Angus Keys (local reserves manager, RSPB, personal communication) during a seabird census around the coastline of The Oa (from a boat) in 2000 (see Table 1).

Approximately even numbers of adult males and females were recorded. However, it should be noted that considerably more adult males than adult females (ca 170 cf. 80) have been culled from the population between 1997 and 2003 (DJM, unpublished data). Goats have been culled on The Oa each year since 1994. Initially only very small numbers were removed from the population. However, with the exception of 1998 (when 10 goats were culled),

between 40 and 50 goats have been culled there annually since 1997. These culls have usually consisted of four to six adult billies and about 35 to 40 adult nannies and kids.

Fifty-two first-year kids were identified in the count, representing at least 12% of the counted population, although this may also be an under-estimate because many were of a comparable size with adult nannies. A small number may therefore have been classed as adult nannies when seen only at briefly.

A total of 45 groups of feral goats were counted, ranging in size from one to 44 individuals. The mean group size of 9.8 animals is considerably larger than the mean group size of about 5 animals in July recorded on nearby Rum (Shi, et al. (b) in press). However, this latter study involved a much larger sample size over a far greater time span.

The study on Rum (Shi, et al. (a) 2003 and (b) in press) showed that group size varies with time of day, generally decreasing as the goats divided into smaller feeding and social groups as they move away from their night caves and increasing again as the goats return to their night shelters. Most groups observed during the survey of The Oa, were recorded between the hours of 10:30 and 18:00. It is therefore likely that fewer, but larger, groups might have been encountered if the survey was undertaken earlier in the morning and later in the afternoon.

Group size and composition also vary throughout the year on Rum, with the percentage of mixed-sex groups increasing sharply during the rut in August and September, and being at its lowest from April to July (Shi, *et al.*, (b) *op. cit.*). Outside of the rut, the frequency of female groups is usually greater than male groups and mixed-sex groups. The relatively high proportion of mixed-sex groups recorded during this survey on The Oa during late July may be indicative of the approaching rut.

Distribution on The Oa

Most goats on The Oa were observed on, or near the coastal cliffs, and mostly less than 500m inland. Several local residents observed that goats headed for the coastal cliffs at the onset of bad weather. Also, during this survey, most goat groups that were disturbed by our presence, usually headed for the coastal cliffs and rocky bays that were within close proximity. Closer examination of the coast revealed that these favoured areas have substantial rock overhangs and former sea caves (from periods of higher relative sea levels) in which the goats clearly seek regular refuge. All shelters had deep deposits of goat droppings on their floors and strong odours of goats prevailed. Impressive examples of these shelters occur in the two bays to the east of Dun Athad and on the south side of the bay at Glen Astle. The goats also shelter amongst and behind some of the larger rockfalls on cliff-slopes and at the cliff-bases.

Coat and Horn Characteristics

The diversity of coat colours and patterns, and adult male horn shapes, observed in The Oa goat population suggest that the population has arisen from several sources. Local residents reported that domestic goats were likely to have escaped or been released at various times over the past 100 or more years. Certainly, there appear to be some goats with 'ancestral' features, including billies with simple, long, scimitar-shaped horns, that may have arisen from older "Scottish-type" stock (see Whitehead 1972). Others have features, such as wider-sweeping, spiralled horns more characteristic of the more recently introduced angora-type goats. While these latter goat traits may have been introduced to The Oa population on more than one occasion, and over a longer period than just two or three decades, three local residents reported that 'angora-type' goats had escaped from a goat farm near Kilnaughton Bay, on the north-eastern portion of The Oa, over the past 20 years or so, and that several had also been deliberately released near The Mull of Oa in about 1995. These accounts are supported by the observation of at least two goats with orange ear-tags seen annually between 1999 and 2002 by RSPB reserve manager, Angus Keys (pers. comm.).

Population Trends

While the data presented here are insufficient to examine population growth trends, there is circumstantial evidence that The Oa goat population is increasing. Firstly, the highest counts (and by a substantial margin) have been recorded in recent years (see Table 1). Secondly, several local residents made the observation that goats are now seen further inland than previously - up to as much as 2km inland in the summer months - and that they have even been seen occasionally on the western outskirts of Port Ellen in the last two to three years. Farmers on The Oa also claim that more goats are being seen than ever before. Interestingly, this is in spite of the numbers of goats that have been culled on farms on both sides of the peninsula, each year since 1994.

Dunbar, Shi, Buckland and Miller (unpublished observations) and Dunbar, Buckland, Miller and Coldbeck (unpublished observations) have shown that the feral goat population of the Isle of Rum - just 120 km north of Islay – appears to be controlled largely by extreme climatic conditions and that population growth is limited mostly by the amount of shelter available in caves and rock shelters in the coastal cliffs. Dunbar, Shi, Buckland and Miller (unpublished observations) have examined climatic influences on the activity budgets of the feral goats on the Isle of Rum and the consequent implications of this for population dynamics under climate change. From this work, they concluded that a mean monthly windchill-adjusted temperature of 5^0C appeared to be a critical threshold in terms of the goats' ability to survive and that caves and other sheltered sites were

an essential component of the animals' survival strategy under such conditions because they effectively raised ambient temperatures for the goats.
Climatic conditions on The Oa are generally less severe than on the Isle of Rum, due primarily to The Oa's lower altitude (200m compared with 400m). Mean monthly rainfalls are also considerably less on Islay (about a third less in most months) and mean monthly temperatures are about 1-2^{0}C warmer. It therefore seems likely that the climatic limitations on the goat population on The Oa may be significantly less than on the population on the Isle of Rum and that the population on The Oa may be increasing.
The feral goat population on The Oa may therefore provide an interesting basis for a comparative study of population growth rates and controlling influences when contrasted with population data from the Isle of Rum, or elsewhere.

Future management of the feral goat population on The Oa peninsula

Madders, et al. (1998) have shown that choughs foraging on The Oa peninsula select grassland habitats to feed in. They showed that in December-February choughs forage preferentially in acidic grasslands and improved grasslands of inland areas. However, in July-September, when the choughs are distributed mostly around the coastline (and have nests mainly in coastal caves), Madders, et al. (1998) showed that they forage preferentially in neutral (dune) grasslands and on cliffs and slopes.
Bullock, et al. (1983) have demonstrated the importance of grazing herbivores to chough feeding ecology, through maintaining the grass sward at a height short enough to allow choughs access to soil invertebrates, while dung beetles (*Aphodius*) found in the faeces of cattle and sheep (and presumably goats) represent an important additional source of prey (Madders, et al. 1998). Shorter swards, as well as areas of bare soil, bare rock and dung, also benefit other thermophilic invertebrates, such as the yellow mound ant (*Lasius flavus*), which the choughs can feed on D. Beaumont, RSPB reserves ecologist, pers. comm.).
Feral goats are now the major vertebrate herbivores with access to the coastal cliffs and the vegetation adjacent to cliff-tops on The Oa peninsula on Islay. Domestic livestock (sheep and cattle) numbers have been reduced significantly on the peninsula in recent years and their access to the dangerous cliffs is now either excluded (in several areas), or is managed carefully to minimise the risk of livestock losses through misadventure.
Browsing and grazing by the goats is therefore the main way that the short sward and floristically diverse vegetation of the cliffs and cliff-top pastures may be maintained, and also potentially expanded in future. In the absence of such ongoing grazing and browsing it is likely that such areas may become colonised by taller, denser, woody perennial shrubs such as heather, willow and bracken.
In addition, the likely high production and at least occasional mortality of feral goat kids will provide prey and carrion for birds such as golden eagle and raven.
Each of these considerations needs to be weighed against other possible conservation outcomes, the potential for degradation of some areas through impacts of too many goats should their population continue to expand, and the affects that annual culling of goats on The Oa peninsula may have on a range of other land management objectives.

b) Other Areas

By comparison with the population on The Oa, feral goat numbers in the north-east, north-west and south-west of the island appear to be considerably smaller. There is insufficient evidence on which to base any conclusion about population trends in these areas. However, more recent figures for both the north-west and the north-east of the island are higher than previous counts or estimates. Closer assessment is needed.
The goat population on the small isle of Texa is interesting for two reasons. Firstly, at the time the survey reported here was undertaken, all 84 goats counted were in a single tribe on the north-western corner of the island. Secondly, these goats apparently supplement their diet with kelp (DJM personal observation).
The relatively larger proportion of adult males to adult females in this population (41:32) may, at least in part, be attributed to some recent population management through culling of some adult females.
As with The Oa population, at least one female goat in the Texa population was noted to have a red ear-tag, suggesting that someone has introduced goats here in the recent past (or, less likely, that someone has been catching and tagging goats on the island).

CONCLUSIONS

The present study has raised more questions than it has answered. The feral goat population on The Oa appears to be increasing in both abundance and range, though this will need to be monitored, using this summary paper as a base-line.
There appear to be some significant similarities and some significant differences between the goat populations on The Oa and on the Isle of Rum. The Oa goat population may therefore provide an interesting and very instructive comparison with the data obtained on Rum – if researchers choose to establish a research program on The Oa.
It is likely that the goat population on The Oa will require ongoing management for both farming and conservation purposes. Any population research that follows this initial baseline survey should help to define what that management should be and where and when it should be applied to best effect.

ACKNOWLEDGEMENTS

We wish to acknowledge Dave Beaumont (RSPB reserves ecologist) for suggesting this project, and to thank Dave and the local RSPB staff – John McGhie and Gus Keys, in particular – for their support and assistance. We also wish to thank Alistair Carmichael of Coillabus farm, Donald Sinclair (senior) of Lower Coillabus farm, Archie Carmichael of Kinnabus Cottage, Ian Carmichael of Fang Dhu and Hamish McTaggart of Kintra farm, for telling us about their observations of the local goats on The Oa. Malcolm Ogilvie kindly provided information on earlier counts of goats on Islay. Estimates of the numbers of goats in the north-east of the island were provided by Jack Adamson, gamekeeper at Islay House. Professor Robin Dunbar of Liverpool University kindly provided background information about the research work conducted on the feral goats on the Isle of Rum. The maps for this paper were kindly produced by Neil Cowie (RSPB reserves ecologist). Anna Copley, Pippa Copley and Rhona Macphee provided valuable field assistance during the survey work.

REFERENCES

Bullock, D.J. and Pickering, S.P. (1984). The validity of horn ring counts to determine the age of Scottish feral goats (*Capra* (domestic)). *Journal of Zoology, London* 202, 561-564.

Bullock, I. D., Drewett, D. R. and Mickleburgh, S. P. (1983). The chough in Britain and Ireland. *British Birds* 76, 377-401.

Finney, S. K. and Jardine, D. C. (2003). The distribution and status of the Red-billed Chough in Scotland in 2002. *Scottish Birds* 24, 11-17.

MacKay, C. R. (1996). Conservation and ecology of Red-billed Chough *Pyrrhocorax pyrrhocorax*. Unpublished PhD thesis, University of Glasgow.

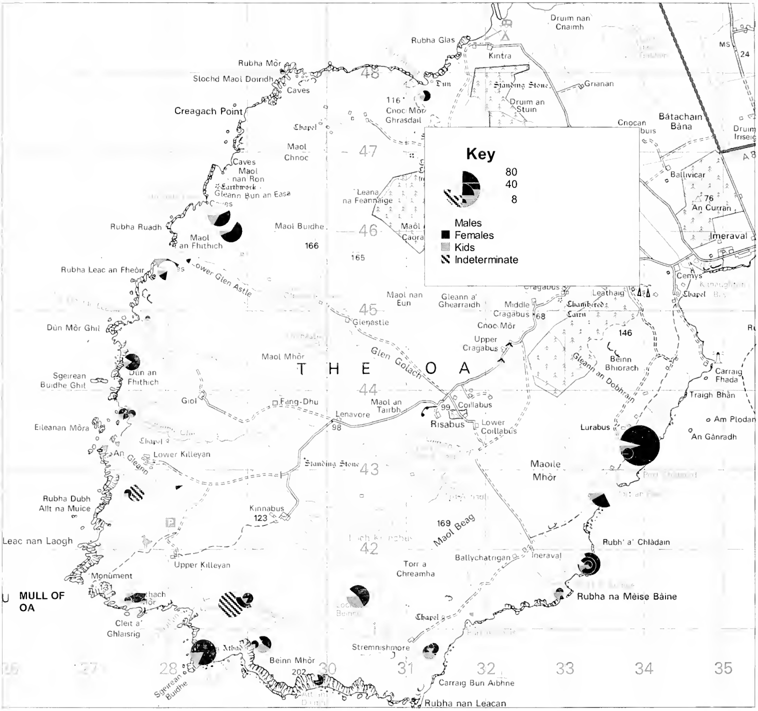
Madders, M., Leckie, F. M., Watson, J. and McKay, C. R. (1998). Distribution and foraging habitat preferences of choughs on The Oa peninsula, Islay. *Scottish Birds* 19, 282-289.

Newton, S. (ed.) (1984). Observations of birds and mammals. *Birds of Islay, 1981-83*. Brathay Field Studies Report, no. 40.

Shi, J., Dunbar, R., Buckland, D and Miller, D. (2003). Daytime activity budgets in feral goats (*Capra hircus*) on the Isle of Rum: influence of season, age and sex. *Canadian Journal of Zoology*, 81, 803-815.

Shi, J., Dunbar, R., Buckland, D and Miller, D. (in press). Dynamics of grouping patterns and social segregation in feral goats (*Capra hircus*) on the Isle of Rum, NW Scotland. *Mammalia*.

Figure 3. The Oa peninsula, Isle of Islay, Scotland, showing place names referred to and indicating the distributon and relative size and composition of feral goat groups observed during July 2003.



Reproduced from Ordinance Survey 1:50,000 scale map with permission of the Crown Controller of Her Majesty 's Stationary Office. Crown Copyright. Licence AL815519.

Figiure 4. Feral goat group size (numbers of goats). The Oa, Isle of Islay – July 2003.

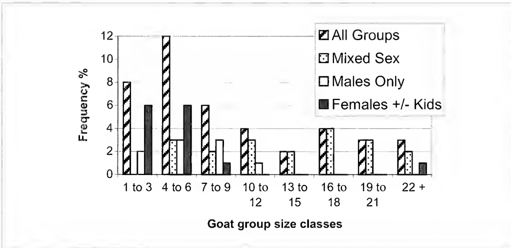


Figure 5. Feral goat colour frequencies. The Oa. Isle of Islay – July 2003.

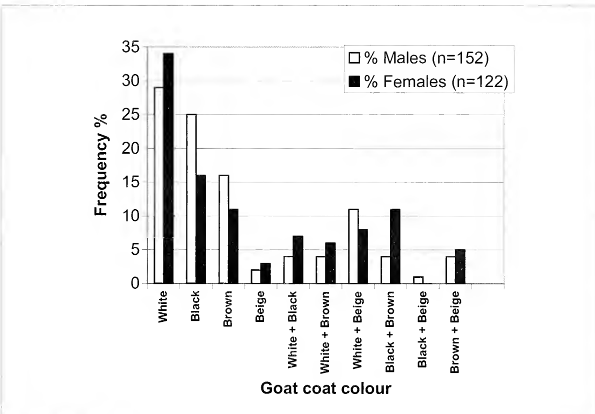


Table 1. Comparison of counts of feral goats made on the Scottish Isle of Islay since1981.

Location	Date	Count / Estimate	Comment
The Oa peninsula	April 1981	123	Malcolm Ogilvie, (pers. comm.)
	Aug. 1983	101	Malcolm Ogilvie, (pers. comm.)
	1984	100-150	Newton (1984)
	Aug. 1985	59	Malcolm Ogilvie, (pers. comm.); island-wide survey
	1998	ca 300	Donald James MacPhee during island-wide deer census by helicopter
	2000	ca 370	A. Keys, (pers. comm.)
	July 2003	ca 400	This survey
NE Islay	Aug. 1985	163	Malcolm Ogilvie, (pers. comm.); island-wide survey
	July 2003	ca 180	Donald James MacPhee
NW Islay	Aug 1985	32	Malcolm Ogilvie, (pers. comm.); island-wide survey
	July 2003	ca 40	Donald James MacPhee
SW Islay	July 2003	ca 70	Donald James MacPhee

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 21-23.

HYDROPORUS SCALESIANUS (COLEOPTERA, DYTISCIDAE) NEW FOR SCOTLAND

G.N.Foster

SAC Research & Development Division, Auchincruive, Ayr KA6 5HW, U.K.

ABSTRACT

Hydroporus scalesianus Stephens, 1828 is a species typically associated with relict fens. It ranges from Ireland, and Les Landes in south-west France to northern Italy, the Czech Republic, and much of Denmark, Fennoscandia, and has recently been recorded as far as West Siberia. This paper describes for the first time the species presence in Scotland.

Adults were were fairly common in Fonah Bog (NO 5350), just west of Balgavies Loch in Angus. The beetles were commonest in a mat of *Calliergon* moss lying over a floating bed of bogbean (*Menyanthes trifoliata* L.), bog myrtle (*Myrica gale* L.) and *Sphagnum* in a shallow, hard-bottomed depression on alluvial deposits. The habitat together with its flora and fauna, including other species of water beetle, is described. The literature on records from outside Scotland is briefly reviewed.

RESULTS

Hydroporus scalesianus Stephens, 1828 is a species typically associated with relict fens. It ranges from Ireland, and Les Landes in south-west France to northern Italy, the Czech Republic, and much of Denmark, Fennoscandia, and Russia (Nilsson & Holmen, 1995), recently as far as West Siberia (Petrov, 2002). In Ireland it is still relatively frequent in lake fens and peat bogs from Tipperary to County Down. Fragments of *H. scalesianus* have frequently been identified in peat deposits because no other *Hydroporus* species is so small and red. Even though this species has a largely northern distribution it has never been reported in Scotland previously.

Adults were fairly frequent in Fonah Bog (NO 5350) on 4 April 2003. The site lies just west of Balgavies Loch in Angus. The beetles were commonest in a mat of *Calliergon* moss lying over a floating bed of bogbean (*Menyanthes trifoliata* L.), bog myrtle (*Myrica gale* L.) and *Sphagnum* in a shallow, hard-bottomed depression on alluvial deposits. The floating carpet ran into a willow carr on one side and beaked sedge (*Carex rostrata* Stokes) on the other. A few specimens could be found in the extreme edge of sedge fen. The fauna was dominated by water hoglice or slaters, *Asellus aquaticus* (L.), and 19 other species of water beetle were found near to but not necessarily in immediate association with *H. scalesianus*. These were *Haliplus ruficollis* (De Geer), *Hygrotus inaequalis* (Fab.), *Hydroporus angustatus* Sturm, *H. erythrocephalus* (L.), *H. palustris* (L.), *H. striola* (Gyllenhal in Sahlberg), *H. umbrosus* (Gyllenhal), *Agabus bipustulatus* (L.), *A. congener* (Thunberg), *A. unguicularis* (Thomson), *Ilybius ater* (De Geer), *Rhantus exsoletus* (Forster), *Anacaena lutescens* (Stephens), *Enochrus coarctatus* (Gredler), *E. ochropterus* (Marsham), *Hydrobius fuscipes* (L.), and *Cercyon tristis* (Illiger). Of special interest was a single male of *Acilius canaliculatus* (Nicolai) a species previously known from Angus in Restenneth Moss and Fithie Loch, taken by Professor Frank Balfour-Browne in 1908 and 1947 respectively. Several individuals of *Hydrochus brevis* (Herbst) were found in the sedge fen margin, a new record for Angus.

H. scalesianus has Red Data Book (RDB) 2 status in Britain (Shirt 1987), *H. brevis* having RDB 3 status, and *A. canaliculatus* provisional RDB 3 status (Hyman & Parsons, 1992).

H. scalesianus was originally named in honour of a Mr Scales of Beechamwell, West Norfolk, but it was not until 1977 that the species was rediscovered in that area, in richly vegetated ponds on the Brecks (Foster, 1982). The species was especially well known from Askham Bog, mid-West Yorkshire (Balfour-Browne, 1940) from 1857 until the end of the 19th Century. Balfour-Browne (1940) found *H. scalesianus* infrequently in the Norfolk Broads during his 1904-6 survey, and it was found spasmodically at Sutton Broad (1926) and Catfield Fen (1923 and 1932) until the 1970s, since when it has become more widespread in the fenland surrounding the Broads (personal observation).

Balfour-Browne (1940) discussed three further English records for *H. scalesianus*, from Hebden Bridge, south-west Yorkshire ca 1830, from Boxmoor, Hertfordshire and from the Portsea area of South Hants up to 1880. He thought it unlikely that these records were due to wrong identification, and he has been proved right for Boxmoor, E.G. Elliman's material in the National Museum of Wales, Cardiff including a specimen from Boxmoor taken in the summer of 1901 (Foster, 1990). The Portsea record has greater credibility following Jeff Robinson's discovery of a site at Sandford Bridge, Dorset in 1997, and, of course, the Hebden Bridge record is supported by the beetle's former occurrence at Askham Bog, and the beetle's recent rediscovery in Yorkshire, beside Hornsea Mere, by Hammond (2002).

Horsfield and Foster (1982) reported *H. scalesianus* in a small, peat-filled kettlehole in County Durham in 1978. Bilton (1984) discovered *H. scalesianus* in Cumberland, at Biglands Bogs, in 1983. Bilton (1988) was also the first to detect it in Ireland, in 1986.

The post-glacial subfossil records are concentrated in the Somerset Levels (Girling, 1984), often in sufficient numbers through peat monoliths to indicate survival over the whole transition from lake fen to raised bog. These records also range

from the Neolithic (5170 before present – B.P.) to post-Iron Age (ca 1700 B.P.), and records continue to accumulate from other post-Glacial deposits, most notably Lindow Man in Cheshire (Dr M H Dinnin, pers. comm. – see also the BUGS2000 data-base – Buckland *et al.* 2002).

DISCUSSION

This compilation of records is a mixture of relict status and discovery, the latter possibly even indicating a recent extension of range. *H. scalesianus* is amongst a group of fenland insects largely confined to relict fen and unknown to colonise habitats of man-made origin. At one stage (Foster, 1982) the British distribution suggested association with relict ponds in the periglacial zone of the most recent Ice Age, but this possibility has been disposed of most effectively by the Cumbrian and Scottish finds. As a member of the relict fen group, *H. scalesianus* might be expected to be flightless. One specimen has been detected in a flight trap in south-east Sweden (Lundkvist, Landin and Karlsson, 2002), so recent occupancy of relict sites retaining high quality habitat cannot be ruled out. However, the most likely scenario, given the species' association with relict sites and other species considered to have relict status, is that we are simply accumulating knowledge of a fragmented distribution by deploying a relatively small number of observers.

An interesting feature of the present day distribution, as opposed to what is known from the fossil record, is that most modern British sites are a relatively short distance from the sea, suggesting increased dependency on a mild coastal climate. The continued wider distribution within Ireland might lend support to this idea, but it is negated by the loss of the species from fens around the Severn estuary, and, of course, by what is known of the extensive distribution in Continental Europe.

ACKNOWLEDGEMENTS

I am grateful to Dr J A T Woodford for arranging access to the site, which is part of the Scottish Wildlife Trust Reserve of Balgavies Loch. Mr Brian Nelson updated my knowledge of the status of *H. scalesianus* in Ireland. SAC receives financial support from the Scottish Executive Environment & Rural Affairs Department.

REFERENCES

Balfour-Browne, F. (1940). *British Water Beetles*. Volume 1. London, Ray Society.

Bilton, D.T. (1984). Four water beetles (Col., Dytiscidae) new to Cumberland, including *Hydroporus scalesianus* Stephens. *Entomologist's Monthly Magazine* 120, 251.

Bilton, D.T. (1988). A survey of aquatic Coleoptera in central Ireland and the Burren. *Bulletin of the Irish Biogeographical Society* 11, 77-94.

Buckland, P.C., Buckland, P.I., YuanZhuo, D. & Sadler, J. (2002). *Bugs Coleopteran Ecology Package* [CD-ROM].

Foster, G.N. (1982). Notes on rare Dytiscidae (Coleoptera) in Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society* 26, 3-10.

Foster, G.N. (1990). *Hydroporus scalesianus* in the British Home Counties in 1901. *Balfour-Browne Club Newsletter* 46, 13.

Girling, M.A. (1984). Aquatic Coleoptera in the fossil insect assemblages from archaeological sites in the Somerset Levels. *Balfour-Browne Club Newsletter* 30, 1-11.

Hammond, M. (2002). A preliminary survey of the water beetles of Hornsea Mere, East Yorkshire (England), including the rediscovery of *Hydroporus scalesianus* in Yorkshire. *Latissimus* 15, 1-3.

Horsfield, D. & Foster, G.N. (1983). *Hydroporus scalesianus* Stephens and *Laccornis oblongus* (Stephens) (Col., Dytiscidae) in Hart Bog, County Durham. *Entomologist's Monthly Magazine* 119, 62.

Hyman, P.S. & Parsons, M.S. (1992). *A review of the scarce and threatened Coleoptera of Great Britain, Part 1*. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 3.)

Lundkvist, E, Landin, J & Karlsson, F. (2002). Dispersing diving beetles (Dytiscidae) in agricultural and urban landscapes in south-eastern Sweden. *Annales Zoologici Fennici* 39, 109-123.

Nilsson, A.N. & Holmen, M. (1995). *The aquatic Adephaga (Coleoptera) of Fennoscandia and Denmark. II. Dytiscidae.* Fauna Entomologica Scandinavica 32, Leiden, E.J. Brill.

Petrov, P.N. (2002). The aquatic Adephaga beetles (Coleoptera) of southern Tyumen Region. *Bulletin of Moscow Society of Naturalist, Biological Series* 107 (3), 31-38 [in Russian].

Shirt, D.B. (Ed) (1987). *British Red Data Books: 2. Insects*. Peterborough, Nature Conservancy Council.

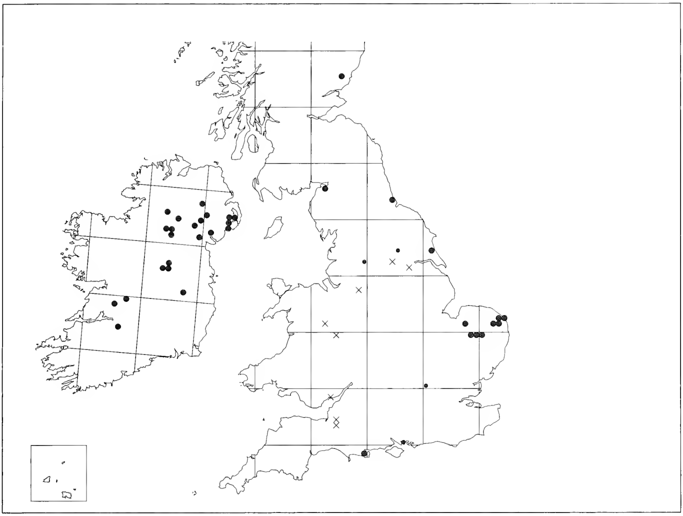


Fig. 1. Distribution of *Hydroporus scalesianus* in Britain and Ireland. Large circles represent 10 km squares in which the species has been found from 1980 onwards, smaller circles earlier records of living beetles, and the crosses post-glacial fossil fragments, with the most recent records taking priority

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 25-28.

THE EFFECT OF WATER CONTENT AND COMPACTNESS OF SOIL ON THE SURVIVAL OF THE NEW ZEALAND FLATWORM *ARTHURDENDYUS TRIANGULATUS*

Peter H. Gibson and Derek J. Cosens

Institute of Cell, Animal and Population Biology, University of Edinburgh, Ashworth Laboratories, West Mains Road, Edinburgh EH9 3JT

ABSTRACT

In an Edinburgh allotment from February to June the soil immediately beneath surface debris where the flatworm *Arthurdendyus triangulatus* was found contained 30% water. When specimens of *A. triangulatus* were allowed to desiccate at 20°C in the laboratory, 50% survived a body water loss of 23% by weight. Specimens, when presented with a choice of soils with differing water contents in a vermarium, chose soil containing 30% water by weight. In a Petri dish study at 10°C, 50% of specimens survived on soil with 16% water, while 90% survived on soil with 27% water. In another vermarium study *A. triangulatus* chose loose soil over compacted soil. The water content of the soil is argued to be one of the key factors in determining the distribution of *A. triangulatus* in Great Britain.

INTRODUCTION

The New Zealand flatworm *Arthurdendyus triangulatus* (Dendy) (formerly *Artioposthia triangulata*, see Jones and Gerard, 1999) is a predator of earthworms and has become endemic to Scotland after being accidentally introduced some 37 years ago (Boag, Yeates, Johns, Neilson, Palmer and Legg, 1995). The general biology of *A. triangulatus* was reviewed by Cannon, Baker, Taylor and Moore (1999), and Jones and Boag (2001) have given an historical account. It is typically found on the soil surface under items of debris such as wooden planks and plastic bags filled with compost, but principally occupies earthworm burrows within the soil. The under-surfaces of long-standing debris have the environmental characteristics of burrows and are a ready source of earthworms (Lillico, Cosens and Gibson, 1996; Gibson and Cosens, 2000a,b). The debris and burrows, in effect, act as refuges for *A. triangulatus* (and other invertebrates) against desiccation to which it is very vulnerable. This paper examines the role of soil water content on the survival and distribution of *A. triangulatus*.

GENERAL PROCEDURES

Specimens of *A. triangulatus* and soil samples were collected from Midmar Drive allotment in Edinburgh, Scotland (Ordinance Survey sheet 66, grid reference NT 252707). The soil in the allotment was a loam derived from a glacial till consisting of a reddish sandy silt-clay of carboniferous sandstone origin containing a proportion of organic material added over the years by gardeners. Specimens of *A. triangulatus* of 0.5-1.0 g body weight were collected from under debris and stored in the laboratory on fresh compacted allotment soil in 90 mm diameter soda glass Petri dishes at 10°C in a refrigerator. The soil used in the dishes was sieved through a 3 mm mesh. Death of the specimens resulting from experiments was indicated by a lack of movement when they were placed in cold tap water. Living flatworms typically revived immediately.

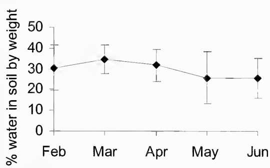
METHODS AND RESULTS

What is the normal water content of the allotment soil?

From February 1st to June 26th soil samples were taken to a depth of 100 mm from under items of debris (plastic sheeting, wooden planks and stones) lying on the soil surface of the allotment. These samples were compared with 10 soil samples taken nearby from directly beneath turf. To establish their water content (θ_g) by gravimetric analysis, each was placed in a plastic bag which was immediately sealed. In the laboratory 150 g of each sample was dried in an oven at 100°C for 24 h, allowed to cool over silica gel in a desiccator and reweighed. (The dried soil was stored in the desiccator for use in other experiments).

The mean water content (θ_g) of 26 samples of soil collected from under debris was 30.1% (SD = 10.0, Fig. 1) and that for 10 soil samples collected from under turf was 22.0% (SD = 8.1).

Fig. 1. The mean percentage water content by weight of soil samples taken from beneath debris in Midmar Drive allotment, Edinburgh, during the spring and early summer (error bars show standard deviations).



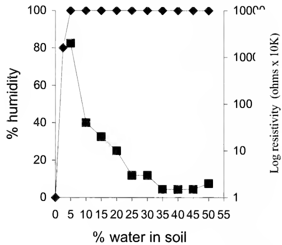
How are relative humidity, resistivity and the water content of soil related?

In the laboratory 200 g of oven-dried soil, sieved using a 3 mm mesh, was placed in a 60 mm deep by 120 mm diameter crystallising dish. After settling the soil into a layer, a hair hygrometer was placed on the surface and the dish was sealed with a glass lid and petroleum jelly. The dish was then placed in a refrigerator at 10°C for 24 h. After removing the dish from the refrigerator the hygrometer was read and removed. The resistivety (ohms) of the exposed soil was measured using an avometer with the two

electrodes placed 50 mm apart. This procedure was repeated 12 times for differing degrees of soil dampness within the range 0-50%. The soil was dampened initially by adding 50 mm^3 of tap water and mixed thoroughly to give a measure of 2.5%. The other 10 degrees of soil dampness were produced by adding multiples (1-10) of 100 mm^3 of tap water and mixing. Additional comparative measurements were made using soil that had been compacted, and with the electrodes separated by multiples of 10 mm up to 90 mm.

Where there was only 5% water in the soil at 10°C in the sealed container the relative humidity of the air above the soil was 100%. The soil resistivity measured in ohms gave a calibration curve for the range of water content (Fig. 2) against which the survival of *A. triangulatus* was later assessed (Fig. 3). Soil compactness and the distance between the electrodes had no effect on resistivity.

Fig. 2. Percent humidity (♦ left axis) and resistivity measurements in ohms (■ right axis) in and above the sieved allotment soil of varying water content in a crystallising dish with an airtight lid kept for 24 h at 10°C.



What degree of water loss is lethal to A. triangulatus *when exposed to air?*

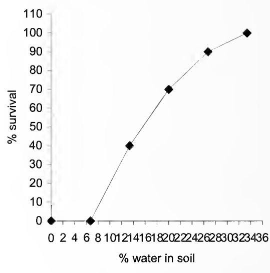
Thirty specimens were placed in cold tap water for 30 minutes to obtain a standard level of hydration. Each specimen was then blotted with filter paper and allowed to dehydrate at 20°C to a specified weight while on an electronic balance. Two specimens were used for each measurement over a water loss of 10% to 25% of their initial hydrated weight. The specimens were then re-hydrated for 30 minutes, placed on damp allotment soil in Petri dishes in a refrigerator set at 10°C and observed over the following 48 h to determine their survival.

All specimens that lost 18% or less of their initial body weight survived the treatment, while those that lost 25% or more died (Table 1). The survival of specimens dehydrated to a percentage between these values was variable. Of the 30 specimens, half recovered from a water loss of 23% of their original body weight.

Table 1. Survival after re-hydration of 30 specimens of *Arthurdendyus triangulatus* allowed to dehydrate in air at 20 degrees C resulting in a loss of between 11 and 25% of their initial body weight.

% weight loss on dehydration	% Survival
11	100
12	100
13	100
14	100
15	100
16	100
17	100
18	100
19	50
20	100
21	100
22	50
23	0
24	50
25	0

Fig. 3. Survival over eight days at 10°C of groups of 10 specimens of *Arthurdendyus triangulatus* on soil samples containing different quantities of water in Petri dishes.



What is the level of soil water content at which A. triangulatus *will die when on soil beneath a cover?*

Sixty specimens were kept for eight days in Petri dishes on dampened oven-dried soil. Water was added to 30 g of the dried allotment soil in each dish and mixed thoroughly. The resulting percentages of water in the soils used were: none, 6.6% (20 mm^3), 13.3% (40 mm^3), 20% (60 mm^3), 26.6% (80 mm^3) and 33.3% (100 mm^3). The soil in each dish was compacted, five specimens were added and the dish sealed with tape. The 12 dishes (two for each dampened soil sample) were each placed in a plastic bag that was also sealed and then

kept at 10°C in a refrigerator. The survival of the specimens was checked every 24 h.

All specimens on soil with a water content of 33% and above survived while all specimens died where the content was below 7 %. Half of the specimens died on soil with a water content at around 15% (Fig. 3). Specimens were always found on the surface of the compacted soil.

Can* A. triangulatus *drown?

Twelve pairs of specimens of *A. triangulatus* were each submerged in distilled water in 90 mm Petri dishes with lids and were kept at room temperature. Pairs were removed in succession at hourly intervals (1 through to 12), transferred to Petri dishes containing dampened compacted sieved soil and their survival observed over the following 48 h. The experiment was repeated for 24, 36 and 48 hours submersion. A control pair of specimens was kept on dampened soil.

Specimens survived submersion for periods up to 48 h. Within an hour of submersion they became flaccid and were incapable of movement but regained their normal appearance and behaviour within 48 h of being out of water.

***What degree of soil dampness is preferred by* A. triangulatus?**

The dry allotment soil was divided by weight into six parts, one was kept dry and the others had water mixed in to give five degrees of dampness expressed as percentages of water by weight, θ_g, (Table 2). One dry part and three with different water contents were packed into separate quarters of a rectangular horizontal vermarium with internal dimensions of 600 mm long by 440 mm wide by 10 mm deep. Two artificial earthworm burrows were made diagonally from the corners so that each crossed a soil quarter. They were produced by pressing an 8 mm diameter doweling rod into the soil and then carefully removing it. Eight 0.5 g specimens of *A. triangulatus* were placed in the artificial burrows: four at the central intersection and one half way along the diagonal crossing each soil portion. The upper glass face of the vermarium was lightly pressed into position on the soil and sealed along the edges with a small quantity of silicone-sealant used in the construction of aquaria. The vermarium was left in the dark for 48 h at 10°C after which the positions of the specimens were recorded. The experiment was replicated five times with different combinations of dampened soil, each degree of dampness being used three times in a combination with a dry soil portion, which acted as a baseline. An identical vermarium in which the four parts of soil had 30% water by weight was used as a control.

After 48 h the specimens in the four quarters of the vermarium and at the centre had dispersed. The majority were found in the artificial burrows running through soil with 20% to 30% water by weight (Table 2). This gave a significantly different distribution compared with the expected result of two specimens for each quadrant ($P < 0.001$, $\chi^2 = 220$, $df = 5$). By contrast, the specimens in the control vermarium with soil of 30% water content moved only a few centimetres from the positions at which they had been initially placed.

Table 2. The distribution of specimens of *Arthurdendyus triangulatus* in a horizontal vermarium containing soil samples of different moisture content in each of the four quarters. The experiment was repeated five times with eight specimens to give a total of 40 specimens.
* dry sample present in all tests.

% water in the quarters	No. Repl.	Distribution		Final distrb. % of total
		Start	48 h	
0 *	5	5	3	7.5
10	3	3	3	7.5
20	3	3	19	47.5
30	3	3	14	35
40	3	3	1	2.5
50	3	3	0	0
Central	5	20	0	0

Does soil compactness influence the choice of location?

The vermarium, of the type described above, was stood vertically and, with its front sealed in place, half filled from the top, which had been opened, with a known weight of dampened soil. The soil was then packed down by repeatedly tapping the vermarium on the floor to give a bulk density of 13 g mm^{-3}. Eight specimens of *A. triangulatus* were dropped onto the surface of the soil and the space above filled with a known weight of similar soil to give a bulk density of 8 g mm^{-3}. The positions of the specimens were recorded after the vermarium had been sealed and left in the dark for 48 h at 10°C. The experiment was replicated three times and a control vermarium containing only loose soil was used.

After 48 h, of the 24 specimens in the experimental vermarium four were found at the interface between the compacted and loose soils and the remaining 20 (83%) were all in the loose soil. None were found in the compacted soil. In the control vermarium the specimens moved in random directions for short distances.

DISCUSSION

To survive for any length of time, *A. triangulatus* requires a damp habitat. Specimens dehydrate when exposed to air on a dry surface and die after losing a quarter of their initial body weight. They will, however, live for weeks in Petri dishes without soil but covered with cling film on which water has condensed. When soil in a sealed container had 5% or more water the air above the soil was saturated. Yet, even with air of high relative humidity (Fig. 2),

A. triangulatus will die if it remains on soil with a low water content (Fig. 3). Death resulted because the suction pressure, pF, (White, 1987) of the soil removes water from *A. triangulatus*. For survival, *A. triangulatus* needs to be on or in soil with a gravimetric water content of 30%. In a vermarium and under debris in the allotment specimens of *A. triangulatus* selected soil with this water content. Very damp soils do not appear to be detrimental since specimens survived total immersion for at least 48 hours. In Scotland, where rainfall often saturates soils, the surface water typically drains away within that period. We may infer that the soil water content rather than temperature is the more important parameter in determining the geographical distribution of *A. triangulatus* in Great Britain. The laboratory experiments showed that specimens of *A. triangulatus* retreat into the soil when the surface temperature was lowered (Gibson, Ponder and Cosens, 2004). In the allotment the temperature at a depth of some 300 mm rarely exceed the upper and lower lethal limits for *A. triangulatus*. However, under natural conditions the soil could dry out at this depth should the water table fall.

In the soil compactness study, where burrows were not present, specimens of *A. triangulatus* chose loose rather than compacted soil. Presumably this is because movement within loose soil is possible and does not require an ability, which *A. triangulatus* lacks, to burrow. When burrows are present, specimens of *A. triangulatus* use them in preference to moving through the soil *per se* (Lillico *et al.*, 1996). Whilst there may be a geotactic effect, none was apparent in the present studies or those of other workers (Cannon *et al.*, 1999).

Since the numbers of *A. triangulatus* in the environment have never been reported to increase exponentially we may assume that a large proportion of the population dies before reproducing. Young specimens are most likely to be vulnerable. Whether predation is important in limiting numbers is not known. However, carabid and staphylinid beetle larvae have been reported to feed on *A. triangulatus* in its natural habitat (Gibson *et al.*, 1997; observation by Anna Gibson, August 2002). Also, when exposed on the soil surface *A. triangulatus* is eaten by farm-yard ducks and geese (Jones and Boag, 2001) and by frogs in the laboratory (Anna Gibson, personal communication). Although predators may be individually insignificant in controlling *A. triangulatus* population, they may be collectively effective. Environmental conditions produced by rainfall and temperature will affect the abundance of potential invertebrate predators. Under some conditions or in different seasons or years predators may be numerous and, therefore, have a significant affect on *A. triangulatus* numbers. Of course, the juvenile stages of *A. triangulatus* and potential predators (in this case, the beetles and their larvae) must occur in the same place and at the same time.

ACKNOWLEDGEMENTS

We wish to thank Keith Hood and Simon Lillico for their help in collecting data used in these studies.

REFERENCES

Boag, B., Yeates, W.G., Johns, P.M., Neilson, R., Palmer, L.F. and Legg, R.K. (1995). Distribution of the New Zealand flatworm (*Artioposthia triangulata*) in New Zealand and Scotland. *Acta Zoologica Fennica* 196, 212-214.

Cannon, R.J.C., Baker, R.H.A., Taylor, M.C. and Moore, J.P. (1999). A review of the status of the New Zealand flatworm in the UK. *Annals of Applied Biology* 135, 597-614.

Gibson, P.H. and Cosens, D.J. (2000a). Density of the New Zealand flatworm, a predator of earthworms, in allotments in Edinburgh between 1993 and 1995. *Annals of Applied Biology* 137, 347-352.

Gibson, P.H. and Cosens, D.J. (2000b). Studies on the local dispersal of the New Zealand flatworm, a predator of earthworms, in allotments in Edinburgh between 1993 and 1995. *Annals of Applied Biology* 137, 353-359.

Gibson, P.H., Cosens, D.J. and Buchanan, K. (1997). A chance field observation and pilot laboratory studies of predation of the New Zealand flatworm by the larvae and adults of carabid and staphylinid beetles. *Annals of Applied Biology* 130, 581-585.

Gibson, P.H., Ponder, K.L. and Cosens, D.J. (2004). The effect of temperature on the survival and distribution of the New Zealand flatworm *Arthurdendyus triangulatus*. *Glasgow Naturalist* In Press.

Jones, H.D. and Boag, B. (2001). The invasion of New Zealand flatworms. *Glasgow Naturalist* 23, 77-83.

Jones, H.D. and Gerard, B.A. (1999). A new genus and species of terrestrial planarian (Platyhelminthes; Tricladida; Terricola) from Scotland and an emendation of the genus *Artioposthia*. *Journal of Natural History* 33, 387-394.

Lillico, S., Cosens, D. and Gibson, P. (1996). Studies on the behaviour of *Artioposthia triangulata* (Platyhelminthes; Tricladida), a predator of earthworms. *Journal of Zoology, London* 238, 513-520.

White, R.E. (1987). *Introduction to the principles and practice of soil science*. Blackwell Scientific Publications, London.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 29-33.

THE EFFECT OF TEMPERATURE ON THE SURVIVAL AND DISTRIBUTION OF THE NEW ZEALAND FLATWORM *ARTHURDENDYUS TRIANGULATUS*

Peter H. Gibson, Katherine L. Ponder and Derek J. Cosens

Institute of Cell, Animal and Population Biology, University of Edinburgh, Ashworth Laboratories, West Mains Road, Edinburgh EH9 3JT

ABSTRACT

In the early spring, temperatures below the soil surface and under items of surface debris such as plastic sheeting were greater than those at the exposed surface. The population density of *Arthurdendyus triangulatus* on the soil surface immediately under debris was positively correlated with the soil surface temperature. However, temperature alone could not account for differences in the densities of *A. triangulatus* under the debris. In the laboratory most specimens of *A. triangulatus* were unable to survive freezing for more than an hour. At low temperatures they became more active at first but then became sluggish. In earth-filled vermaria *A. triangulatus* typically avoided adverse temperatures by moving down the soil column. It tolerated temperatures up to 23°C but showed a preference for 19°C. Some three times as many earthworms were eaten by *A. triangulatus* when the soil was at 10°C than at 3°C.

INTRODUCTION

The accidental introduction of the New Zealand flatworm *Arthurdendyus triangulatus* (Dendy) (formerly *Artioposthia triangulata*, see Jones and Gerard, 1999) into Britain nearly forty years ago presents a potential threat to the numbers and species of earthworms. *A. triangulatus* has become established throughout Northern Ireland and Scotland (Willis and Edwards, 1977; Boag, Yeates, Johns, Neilson, Palmer and Legg, 1995) and is now found in England (Boag, Neilson, Palmer, and Jones, 1994). It typically occurs in urban areas and has probably been spread as egg capsules in the soil of bedding plants bought at garden centres and market gardens. The general biology and distribution of the species have been reviewed by Cannon, Baker, Taylor and Moore (1999), who concluded that there is 'need for a better understanding of the environmental conditions under which *A. triangulatus* survives'. Accordingly, this paper examines the effect that temperature has on the survival of *A. triangulatus*.

GENERAL PROCEDURES

Field studies were carried out at Midmar Drive allotment, Edinburgh, Scotland (Ordinance Survey sheet 66, grid reference NT 252707). Specimens of *A. triangulatus* of varying body weight were collected from under debris for use in laboratory studies. They were kept for up to 7 days on fresh compacted allotment soil in 9 cm diameter soda glass Petri dishes at 10°C in a refrigerator. The soil was a loam derived from a glacial till consisting of a reddish sandy silt-clay of carboniferous sandstone origin.

METHODS AND RESULTS

What is the typical soil temperature profile in the early spring?

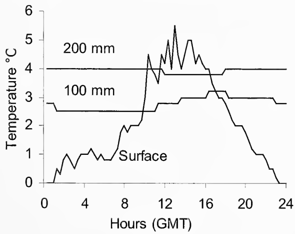
From February 10th to March 10th 1995 the soil temperature was recorded every 15 minutes using thermisters connected to a four channel automatic temperature recorder powered by a 12 V battery (Grant Instruments Ltd, Cambridge). Three thermisters were inserted horizontally into the vertical side of an excavated pit at depths of 100, 200, and 400 mm and the pit was then refilled with the original soil. The fourth thermister was placed on the soil surface.

Over 24 h the temperatures within the soil column fluctuated in a regular manner (Table 1, Fig. 1): at the surface there was a range of 6.2°C; at 100 mm 1.5°C; at 200 mm 0.7°C; at 400 mm 0.4°C.

Table 1. Mean maximum and minimum soil temperature (°C) at different soil depths over a period of 23 days from 10 February to 10 March (±SD standard deviation; also see Fig. 1).

Surface		**100 mm depth**	
Min	Max	Min	Max
-0.35	5.88	1.83	3.37
±1.76	±2.39	±0.80	±1.52
200 mm depth		**400 mm depth**	
Min	Max	Min	Max
3.33	4.01	3.70	4.11
±0.41	±0.95	±0.30	±0.67

Fig. 1. Allotment soil temperature profiles for the 10th February at three depths (since the temperature at 400 mm fluctuated little from 4°C and was so similar to that at 200 mm it is omitted from the graph). The profile is typical for the 29 days of the study (also see Table 1).

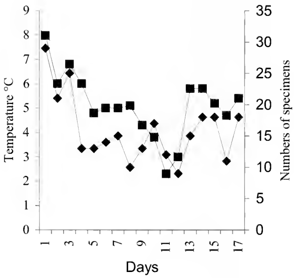


How do* A. triangulatus *numbers relate to variation in soil surface temperature?

Soil temperature and numbers of *A. triangulatus* under debris were recorded over 17 days from March 19th. Numbers were monitored under 17 items of debris (13 wooden planks, 2 plastic sheets and 2 stones) evenly distributed over the soil surface and covering a combined area of 40 m^2 within a 400 m^2 area of cultivated soil. The soil temperature was recorded at midday from a 10 mm depression beneath a flat stone at the centre of the experimental area. Without moving the stone a thermister probe of the Grant recorder was carefully inserted into the depression to record the temperature.

At midday the temperature ranged from 2.5 to 8.0°C. The numbers of specimens of *A. triangulatus* found correlated significantly with the soil surface temperature (Fig. 2) (Spearman's rank correlation r = 0.67, P<0.001).

Fig. 2. Numbers of *Arthurdendyus triangulatus* (◆) on the soil surface under debris lying within 400 m^2 over 17 days in March and April and temperature (■) recorded in a shallow pit below a flat stone over the same period.

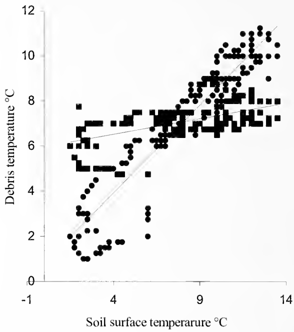


How does soil surface temperature compare beneath two different types of debris?

The soil surface temperatures were recorded under two recycled 600 x 900 mm plastic 'feed' sacks filled with compost, a 50 mm thick concrete paving stone and at the soil surface over five days from March 12th to 16th. One sack regularly had specimens of *A. triangulatus* beneath it while the other had none. The sacks were 5 m apart.

During a 24 h period temperature under the two compost-filled plastic sacks fluctuated in a similar manner from 5 to 9°C, a range of 4°C. The mean temperature for the sack with specimens of *A. triangulatus* was 7.1°C (SD = 2.6) and without specimens it was 7.3°C (SD = 1.0). Under the paving stone it fluctuated from 1 to 11°C, a range of 10°C. Since the exposed soil surface temperature ranged from 1 to 14°C, a range of 13°C, compost-filled plastic sacks clearly buffered the changes in temperature over 24 hours. By contrast, the paving stone had a limited buffering effect (Fig. 3).

Fig. 3. Temperature over the 12th to 16th March under a paving stone (●) (regression line, R^2 = 0.8767, P < 0.001) and a compost-filled plastic sack which had many specimens of *Arthurdendyus triangulatus* under it (■) (regression line, R^2 = 0.2526, P < 0.001) (R^2 = 0.3055 & P < 0.001 for the sack, data points not shown, under which specimens were not found but the temperature had the same distribution).



What is the cold tolerance of* A. triangulatus*?

A plastic tray of 600 x 400 x 100 mm was filled with water to a depth of 30 mm and six glass specimen tubes of 75 x 25 mm were stood upright at one end. A 200 mm diameter cooling coil was placed at the other end of the tray which was then lagged. When the water froze a specimen of *A. triangulatus* was placed at the bottom of each tube which was then sealed with a cork stopper. As the apparatus cooled, the temperature in the tubes fell to -2°C. The specimens were prodded every five minutes over a period of 20 minutes and then every 10 minutes to determine whether they were alive. When a specimen became frosted it was removed from the tube to thaw at 10°C and then gently prodded to determine whether it was alive. Dead specimens disintegrated. The activity of other specimens in Petri dishes in crushed ice was also observed.

Of 49 specimens with body weights of 0.05-1.00 g, 42 (86%) died within 60 minutes. There is a correlation between body weight and survival time (Pearson's correlation r = 0.34, n = 49, P = 0.05). However, this relationship was skewed by seven specimens which survived the longest with one of 0.84 g living for 3 h. Five of these were at the heavier end of the range (mean 0.48 g, SD = 0.24). This compares with 14 specimens of similar weights which died in less than an hour. Some small specimens took refuge under the cork

stoppers and survived longer than they might otherwise have done. Observations on specimens in Petri dishes with crushed ice showed that they became active as the temperature fell and then sluggish before freezing. Their bodies often blistered. Specimens with partially frozen posterior ends survived when thawed and although the frozen ends disintegrated the wounds healed during the following two weeks. Specimens that froze completely disintegrated when thawed as observed earlier.

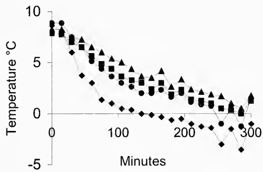
What effect does temperature have on the vertical distribution of* A. triangulatus *in the soil column?

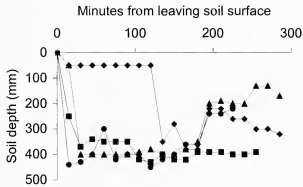
A glass-fronted vermarium with internal dimensions of 600 x 440 x 10 mm was prepared. Five mercury thermometers had been stuck horizontally, with clear silicone-sealant, 100 mm apart on the inner face of the glass front with their bulbs lying along the vertical midline but without touching the glass. The first thermometer was 500 mm from the base and the fifth 100 mm from the base. The vermarium was stood vertically on one of the 440 mm sides and filled to the level of the first thermometer from the upper end with fresh allotment soil that had been sieved with a 3 mm mesh. A doweling rod of 8 mm diameter was pushing vertically into the soil at equal distances apart on the side opposite the thermometers to produce three artificial earthworm burrows. Five specimens of *A. triangulatus*, each of 0.5 g body weight, were placed on the soil surface and the vermarium was closed with a lid that was held in position by clear silicone-sealant. A temperature gradient was created using a flat 200 mm diameter cooling coil placed vertically 20 mm behind the vermarium with its centre level with the upper soil surface. The vermarium was kept in a darkened room at 10°C and illuminated with a dim red light. As a vertical temperature gradient developed from the soil surface downwards over 6 hours the soil temperatures and the positions of the specimens were recorded every 15 minutes. The experiment was repeated four times with fresh soil and different specimens, as well as being repeated without using the cooling coil to give a control.

The temperature of the soil in the vermarium decreased progressively over 300 minutes to produce a gradient from –3.0°C at the soil surface to 1.5°C at a depth of 300 mm (Fig. 4 upper graph). Some specimens froze near the top of the vermarium due to an initial rapid drop in temperature. However, the positions of specimens showed that as the temperature fell most moved down the soil column to stop at a mean depth of 390 mm (SD = 39.2, n = 4) (Fig. 4 lower graph) where the temperature was above 0°C (Fig. 4 upper graph). A Mann-Whitney U-test showed that specimens moved significantly further down the vermarium under the experimental conditions than under the control conditions (median depths: experimental 404 mm, control 20 mm; W = 591, $P<0.001$).

In a similar experiment the temperature gradient was created using a red Philips 250 W heating lamp suspended 200 mm above the soil surface. Temperatures at the various depths and the positions of the five specimens were recorded after 24 h. The experiment was replicated three times with, and three times without, the lamp.

Fig. 4.
Upper Graph.
Soil temperatures in the vermarium as cooling proceeded over 300 minutes at: the surface ◆, a depth of 100 mm ●, 300 mm ▲, and 400 mm ■. The data points are mean values for the four experiments, error bars are omitted for clarity as are data for a depth of 200 mm.
Lower Graph.
The positions of four specimens within the vermarium that remained alive during the cooling period. Each worm, after a lag period at the soil surface (■ 105 min, ◆ 75 min, ● 60 min, ▲ 30 min; mean = 67.5 min, SD = 31.2), moved down into the soil column where it remained until, due to the accumulation of cold air at the bottom of the apparatus (400 - 600 mm), it moved upwards to where the soil temperature was above freezing (see Fig. 4a).





The temperature gradient within the soil column ranged from a mean of 23.3°C (SD = 1.2, n = 3) at the upper soil surface to a mean of 13.7°C (SD = 1.5, n = 3) at a depth of 400 mm. The specimens moved down the soil column during the experiment and after 24 h they were found in positions where the soil temperature was between 15 and 22°C (mean 18.9°C, SD = 2.4, n = 12). As in the

previous study, the specimens moved significantly further down the experimental column than the control column (Mann-Whitney U-test: experimental median depth = 101 mm, control = 22 mm, n = 15, W = 304.5, P<0.003).

***Do low temperatures inhibit the predatory behaviour of* A. triangulatus?**

Two plastic tubes, each 120 mm in diameter and 600 mm long, were positioned 50 mm apart and glued at one end to a sheet of plastic that formed a base. The apparatus was stood vertically and filled with 2.5 kg of fresh allotment soil that had been sieved using a 3 mm mesh. A 200 mm diameter cooling coil was placed half way between the tubes with its centre level with the soil surface. The apparatus was lagged. Ten large specimens of the earthworm *Lumbricus terrestris* L. were placed on the surface of the soil in each tube which was then sealed. The apparatus was left for five days during which the earthworms made burrows. Five 0.5 g specimens of *A. triangulatus* were then placed on the surface of the soil of each tube which was resealed and the apparatus cooled for a week. The contents of the tubes were then examined to determine the number of earthworms eaten. The experiment was repeated and a control was run without the cooling coil. This gave four experimental tubes and two control tubes.

The soil in the experimental tubes cooled to 3°C while the soil in the control tubes remained at a temperature of 10°C. Of the 40 earthworms used in the experimental tubes 34, or about nine tenths, were recovered while of the 20 earthworms in the control tubes nine, or about half, were recovered. Therefore, significantly more earthworms were eaten at the higher temperature ($P < 0.001$, $\chi^2 = 25$, df = 1).

DISCUSSION

In Edinburgh temperatures can vary between -7°C and 25°C (annual record of the Royal Edinburgh Botanic Gardens for 1999). The numbers of *A. triangulatus* found under debris correlated positively with changes in environmental temperature, and in the laboratory, specimens were found to move down the soil column as the surface temperature rose or fell. Some of the items of debris buffered the variations in temperature at the soil surface. In spite of this buffering the densities of specimens cannot be accounted for by the nature of the debris (Gibson and Cosens, 2000a). For example, the numbers of *A. triangulatus* beneath the two compost-filled sacks were different even though they were subject to the same temperature variation. These findings suggest that other physical factors are involved in controlling *A. triangulatus* numbers and the most important of these may be the soil-water content (Gibson and Cosens, 2004). In the heated vermarium, for example, the soil surface became dry and as a result specimens may also have descended the soil column to the avoid desiccation.

In the vermarium studies, *A. triangulatus* was found to be unable to survive freezing for any length of time and descended the soil column when the surface temperature fell below 0°C. *A. triangulatus* was found to be able to tolerate soil temperatures up to 23°C for at least a few hours but preferred soil at 19°C. These findings are consistent with those of Blackshaw and Stewart (1992) who found an upper lethal limit of 24°C and an ability to survive for up to two weeks at 20°C. The lower lethal limit must be just below freezing.

The abundance of *A. triangulatus* in the soil is dependent on a number of factors. One is the predation pressure on earthworms which is indicated by how long *A. triangulatus* has been present at a particular location (Blackshaw, 1990; Lillico *et al.*, 1996; Gibson and Cosens, 2000b). Blackshaw (1991, 1997) found that the numbers of earthworms eaten by *A. triangulatus* increased when soil temperature rose from 5°C to between 12°C and 16°C. Similarly, in this study three times as many earthworms were consumed at 10°C as at 3°C. That is, the biomass of earthworms eaten increases with temperature. This has implications for agriculture in Scotland should the mean annual temperature rise due to global warming. Were this to occur, the threat to earthworm numbers, first noted by Blackshaw (1990), may become a serious reality. Until now the numbers of earthworms and *A. triangulatus* in Scotland appear to have reached an equilibrium dependent on a predator/prey oscillation (Boag *et al.*, 1995; Gibson and Cosens, 2000b) but this balance could alter were temperature to rise. Flatworm consumption of earthworms is unlikely to increase in England because global warming would also result in significant drying of soils which is likely to be a major influence in controlling the distribution of *A. triangulatus* (Gibson and Cosens, 2004).

The conclusion based on this study and those of Blackshaw, is that temperature *per se* may not directly limit the distribution of *A. triangulatus* within Great Britain. *A. triangulatus* appears to tolerate temperatures between freezing and 24°C and has the ability to move sufficiently quickly to avoid extremes (Gibson and Cosens, 1998) by using surface shelters, earthworm burrows or crevices (since it cannot burrow) within the soil. The upper lethal temperature probably depends on thermal inactivation of enzymes (Schmidt-Nielsen, 1979) and is likely to be well above 24°C. The most serious threats to the survival of *A. triangulatus* are, however, likely to be the soil-water content and relative humidity (Gibson and Cosens, 2004) which are, of course, related to temperature.

ACKNOWLEDGEMENTS

We wish to thank Simon Lillico for his help in collecting the data used in this study.

REFERENCES

Blackshaw, R.P. (1990). Studies on *Artioposthia triangulata* (Dendy) (Tricladida: Terricola), a predator of earthworms. *Annals of Applied Biology* 116, 169-176.

Blackshaw, R.P. (1991). Mortality of the earthworm *Eisenia fetida* (Savigny), presented to the terrestrial

planarian *Artioposthia triangulata* (Dendy) (Tricladida: Terricola). *Annals of Applied Biology* 118, 689-694.

Blackshaw, R.P. (1997). The planarian *Artioposthia triangulata* (Dendy) feeding on earthworms in soil columns. *Soil Biology and Biochemistry* 29, 229-302.

Blackshaw, R.P. and Stewart, V.I. (1992). *Artioposthia triangulata* (Dendy, 1894), a predatory terrestrial planarian and its potential impact on lumbricid earthworms. *Agricultural Zoology Reviews* 5, 102-219.

Boag, B., Neilson R., Palmer, L.F. and Jones, H.D. (1994). A further record of the New Zealand flatworm *Artioposthia triangulata* (Dendy) in England. *Plant Pathology* 43, 220-222.

Boag, B., Yeates, W.G., Johns, P.M., Neilson, R., Palmer, L.F. and Legg, R.K. (1995). Distribution of the New Zealand flatworm (*Artioposthia triangulata*) in New Zealand and Scotland. *Acta Zoologica Fennica* 196, 212-214.

Cannon, R.J.C., Baker, R.H.A., Taylor, M.C. and Moore, J.P. (1999). A review of the status of the New Zealand flatworm in the UK. *Annals of Applied Biology* 135, 597-614.

Gibson, P.H. and Cosens, D.J. (1998). Locomotion in the terrestrial planarian *Artioposthia triangulata* (Dendy). *Pedobiologia* 42, 241-251.

Gibson, P.H. and Cosens, D.J. (2000a). Density of the New Zealand flatworm, a predator of earthworms, in allotments in Edinburgh between 1993 and 1995. *Annals of Applied Biology* 137, 347-352.

Gibson, P.H. and Cosens, D.J. (2000b). Studies on the local dispersal of the New Zealand flatworm, a predator of earthworms, in allotments in Edinburgh between 1993 and 1995. *Annals of Applied Biology* 137, 353-359.

Gibson, P.H. and Cosens, D.J. (2004). The effect of water content and compactness of soil on the survival of the New Zealand flatworm *Arthurdendyus triangulatus*. *Glasgow Naturalist* In Press

Jones, H.D. and Gerard, B.A. (1999). A new genus and species of terrestrial planarian (Platyhelminthes; Tricladida; Terricola) from Scotland and an emendation of the genus *Artioposthia*. *Journal of Natural History* 33, 387-394.

Lillico, S., Cosens, D. and Gibson, P. (1996). Studies on the behaviour of *Artioposthia triangulata* (Platyhelminthes; Tricladida), a predator of earthworms. *Journal of Zoology, London* 238, 513-520.

Schmidt-Nielsen, K. (1979). *Animal physiology: Adaptation and environment*. Cambridge: Cambridge University Press. pp 20-213.

Willis, R.J. and Edwards, A.R. (1977). The occurrence of the land planarian *Artioposthia triangulata* (Dendy) in Northern Ireland. *Irish Naturalist Journal* 19, 112-116.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 35-52

STUDIES ON THE CONSERVATION BIOLOGY OF IRISH LADY'S-TRESSES ORCHID, *SPIRANTHES ROMANZOFFIANA;* 1) POPULATION SIZES, GRAZING, VEGETATION HEIGHT AND CAPSULE STATUS AT REFERENCE SITES

Richard Gulliver [1], Mavis Gulliver [2], Margaret Keirnen[3], and Christopher Sydes[4]

[1] and [2] to whom correspondence should be addressed, Carraig Mhor, Imeravale, Port Ellen, Isle of Islay, Argyll PA42 7AL, [3] Grianan, Drumclach, Isle of Colonsay, Argyll, PA61 7YR, [4] Scottish Natural Heritage, 2 Anderson Place, Edinburgh, EH6 5NP

ABSTRACT

Studies were undertaken on Irish lady's-tresses orchid to determine the annual variation in recorded population size; and to examine a range of factors which were considered likely to affect population size, including impact of grazing, means of reproduction and features of the vegetation. Two special attributes of the species, a) the presence of a mycorrhiza and hence a source of organic carbon from the fungus, and b) its status as a Biodiversity Action Plan species; lend special biological and conservation importance to the investigations.

At two sites subject to a grazing break in summer, the number of plants in bloom has risen each year between 1999 and 2002 with a fall in 2003. In every year 65% or more of plants in bloom at these two sites were newly recorded plants. At two sites with no grazing break 1-3 plants had flowering stems in 2002 and 2003, however moderate sized populations were in existence, indicating that the number of plants with flowering stems is not always a useful guide to population size. Data are provided on the impact of grazing on leaves by slugs and vertebrates; and on flowering stems by domestic stock and rabbits.

The locations of the sites studied are referred to by code numbers to reduce the likelihood of visits by collectors of rare orchids.

Spiranthes romanzoffiana plants occurred at a wide range of vegetational heights at six sites including a) two which had experienced grazing breaks since 1996 (in June, July and part or all of August) b) one traditionally managed site with a summer grazing break, c) two with summer grazing and d) one with summer grazing break 1996 to 2000 but not thereafter. At one site they had a tolerance of a regime of heavy grazing by domestic stock which produced low swards. Paired data indicated lower vegetational heights in 2003 cf. 2002 at two sites with a summer grazing break. Measurements of the lowest grazed level created by domestic stock were used to indicate the intensity of grazing and associated activities e.g. trampling and defecation.

At three sites in the same dune system, frequency of *Juncus articulatus* and *Juncus acutiflorus x articulatus* (pooled) ranged from 60% to 28% to 0% in 10x10cm quadrats centred on the positions of *Spiranthes romanzoffiana* plants.

In order to appreciate fully the importance of a range of biotic and abiotic factors and management influences, detailed records are required. Such detailed information may not be easy to summarise and communicate.

Capsules which had developed to full size, and then dried and dehisced, were observed in *Spiranthes spiralis* in England, but not in *Spiranthes romanzoffiana* in Scotland. To gain a more complete understanding of the species, it would be desirable to investigate aspects of sexual and vegetative reproduction under controlled conditions. A long-term objective might also be to experimentally simulate the effects of defoliation, trampling and organic matter input from dung

The fact that *Spiranthes romanzoffiana* can occur in the underground form for up to six years makes long-term study of both the species and its environment especially important, i.e. seven years must elapse after the initial observation before one can assume that a plant at a marked position has died.

Key words and phrases: vegetation height, orchid, population, conservation, grazing, *Juncus* species

INTRODUCTION

Spiranthes romanzoffiana (Irish lady's-tresses orchid: Figures A1, A2, A3, B1) is a white flowered orchid which blooms in July and August. The species occurs in Devon in England and the north, south and west of Ireland. In Scotland it is present in the Hebrides from Islay to Benbecula; and on the west coast. There is also one 1970 record approximately 30km inland from the coastline; for distribution map see Preston, Pearman and Dines (2002). It has recently (August 2002) been found on Tiree (Bowler 2003). It was formerly a British Red Data Book (BRDB) species but botanical exploration and recording in the nineteen eighties and nineties raised the number of heetads (10x10km squares) in which the plant had been found to above the critical level of 15, and it no longer qualified for this status. It is currently a 'Nationally Scarce' species *sensu* Cheffings (2004), i.e. Scarce *sensu* Stewart, Pearman and Preston (1994); and a Biodiversity Action Plan Priority Species, see UK Biodiversity Action Group (1999).

New lateral buds (normally one, sometimes two i.e. twins, very rarely three or four) usually emerge above the soil surface between July and October, so the plant has green tissue present throughout the winter months, see Gulliver *et al.* (2000) for illustrations of the lateral bud, the nature of the inflorescence in September, and for further illustrations of the plant in bloom. As with all members of the Orchidaceae, the species is myco-rrhizal, and so has a source of organic carbon in addition to that generated by photosynthesis.

In the British Isles the other extant member of the genus, *Spiranthes spiralis* (autumn lady's-tresses: Figure A4) occurs in England, Wales and Ireland, but not Scotland. *Spiranthes aestivalis* (summer lady's-tresses) formerly occurred in the New Forest in England, in Guernsey and in Jersey, but is now extinct in the British Isles, Preston, Pearman and Dines (2002).

Spiranthes romanzoffiana can frequently be observed growing amongst the stems of *Juncus acutiflorus x articulatus (Juncus surrejanus),* Figure A1; and of *Juncus articulatus* which is stated to be moderately resistant to grazing by Grime, Hodgson and Hunt (1986). However the absence of stems of *Juncus* species (mainly *Juncus acutiflorus x articulatus*) outside the exclosure at KA on Colonsay, shown in Figure A5, is due to the presence of heavy grazing.

The rhizome system of *Juncus articulatus* is described as subcaespitose (almost tufted) and of *Juncus acutiflorus x articulatus* as far creeping by Blackstock and Roberts (1986). Species with far creeping rhizomes which produce daughter plants at intervals are grazing tolerant, as consumption by grazers can normally only involve part of the total set of ramets. Tufted taxa may suffer total consumption; however the close grouping of the stems may make the mass of vegetation less attractive for plant species of limited palatability. The emergence of stems of other species from underground organs may be partly or wholly impeded by the dense grouping of stems, stem bases and associated roots of tufted plants. The roots of *Juncus articulatus* are sometimes mycorrhizal, Grime, Hodgson and Hunt (1986), and the same may well be the case for *Juncus acutiflorus x articulatus*.

The status of *Spiranthes romanzoffiana* on Colonsay in 1995 and 1996 is given in Gulliver (1996) and (1997); the impact of grazing on plants on Colonsay in 1999 in Gulliver *et al.* (2000) and the impact of grazing in general by Gulliver *et al.* (2003); the results of long term monitoring of plants on Barra by Robarts (2000); the vegetation associated with the species at 16 locations on Coll by Henderson (2001); the genetic constitution of populations in Ireland and Scotland using molecular methods by Forrest (2001) and Forrest *et al.* (2004); and the results of research into the conservation biology of the species in Gulliver (2002). In this account, plant taxonomy follows Stace (1997): English plant names follow the journal house style.

These investigations of small, medium and large sized populations form part of two Scottish Natural Heritage research projects with further funding from the Botanical Research Fund. Studies which involved the use of exclosures on the variable appearance over time of individuals in small populations commenced in 2003, Gulliver *et al.* (2004b, this volume).

The aim of the research was firstly to record the annual variation in number of flowering stems (1999-2003) and for 1999-2001 to record the composition of the populations. Secondly it was to examine a range of factors which are likely to affect population size, including impact of grazing, means of reproduction and features of the vegetation.

METHODS

General

Five sites (LF, KA, KB, KC and SF) on Colonsay were visited regularly throughout the year during the period 1999 to 2001; four less intensively so in 2002 and 2003. Some general recording had taken place previously, between 1991 and 1998. From 1999 onwards individual plants were marked by the use of an adjacent black plastic peg with a 'mushroom shaped' black top. Referencing systems were established to allow plants to be relocated. One site (BB subsite A) was studied on Barra.

Due to a previous history of rare orchids having been periodically dug up in the British Isles, locations are not identified in detail, but are referred to by code letters.

Any one plant may either be in the flowering (F), vegetative (V) or underground (U) phase in any one growing year. By 1999 the longest period a plant had been recorded underground was 4 years (Dr James Robarts *pers comm.,* in Gulliver *et al.* 2000). Continued observations by Dr Robarts on Barra have shown that the longest period recorded underground for any single plant is 6 years (Dr James Robarts *pers. comm.*). Flowering and vegetative plants are differentiated by the presence of a flowering stem, which is sometimes truncated by grazing.

Flowering, vegetative and bud-only plants were recorded during the period of multiple site visits, 1999-2001. Bud-only plants were recorded from July to October and were a) plants appearing above ground having spent the previous 12 months (at least) in the underground state or b) the newly generated second member of a pair of twin buds on a plant (flowering or vegetative) above ground in summer. They are included in the total as they represent part of the population present on site from a conservation perspective, but they are actually in the next growing year to the flowering and vegetative plants present. On multiple site visits plants were occasionally observed in mid to late August or early September with no stem whatsoever. On a previous visit a stem was present. On a system involving a single visit per year recording such plants would be classed as vegetative, on a multiple visit system as flowering. (Plant 6 at site KC on 14 August 2000 is an example of this phenomenon). The cumulative totals detected over all visits in any one year were always higher than the number of plants recorded on a single visit (Gulliver, 2002).

For sites KC and LF the cumulative number detected from August 1999 to September 2001 is

referred to as the 'monitored set', n = 18 and 37 respectively. The 'monitored set' of positions was examined in 2002 (August) and 2003 (May, July and September) at KC and LF. For KA and KB plants in bloom were recorded in August in 2002 and July in 2003. In addition at KA and KB a subset of the population was investigated in July 2003. Shrivelled inflorescences were examined at KA and KB in detail in September 2001, 2002 and 2003.

Site characteristics

Sites KA and KB were protected from grazing by sheep and cattle from very late May/early June to late September/early October in 2001, 2002 and 2003; having been surrounded by fixed, gated exclosures in Spring 2001; Figure A5 shows part of the exclosure round site KA. These populations have diffuse margins. Of the 49 and 25 plants recorded in bloom on all visits to KA and KB respectively in 1999, one at KA (31a) and one at KB (21a) are now outside the exclosure. Outside these two exclosures grazing was more or less continuous in 2001, 2002 and 2003.

The grazing history of the whole area which includes sites KA, KB and KC is complicated. Appendix A gives relevant details from 1991 onwards of a) presence or absence of a summer grazing break over time b) changes associated with the erection of a gated, moor/dune fence in 1996. From 1996 onwards grazing stock might be on either or on both sides of the fence. Prior to its erection they could move freely between moor and dunes.

Site LF was grazed lightly, with considerable variation in the length of the grazing period. Site SF was more or less continuously grazed over the whole area, however it was very variable in nature often resulting in differing and varying intensities of grazing from position to position. Site TG was usually grazed more or less continuously. Site LF is site 1 in Gulliver *et al.* 2000, Site KA is site 2, site KB is site 3 site KC is site 4 and site SF is site 5.

Details of site management and characteristics for the study sites, including adjudged intensity of grazing integrated over all times of year and all types of vegetation within the site are provided in Appendix A and B. Some parts of site KA were very marshy, periodically resulting in the sinkage of single or groups of marker pegs and an absence of detectable plants in highly disturbed ground. A degree of peg sinkage also occurred at LF, KB, and KC. Dates of visits are given in the relevant tables.

At site BB subsite A on Barra the management is relatively constant every year, stock are absent in June, July and August. Frequently sheep are kept on the whole area of unenclosed croft land, which includes subsite A, for longer than cattle in the spring, and they are often brought back in the autumn in advance of the cattle. In general a greater degree of regularity of management occurs at sites which are managed by a grazing committee or by a group of crofters following an agreed procedure each year, compared with those that are not.

Vegetation height and *Juncus acutiflorus x articulatus* plus *Juncus articulatus*

Vegetation height was recorded as an index of the intensity of use of the area by domestic stock, e.g. very low heights indicate heavy grazing, tall heights indicate light grazing, variable heights indicate patchy (selective) grazing on either a more or less uniform sward or on a mixture in the sward of plants of differing palatability. Three height bands have been used by MacDonald *et al.* (1998a and 1998b) to assess, together with other measurements, the intensity of grazing in four habitats in upland Scotland, (smooth grassland, flush, tall herb and tussock grassland).

In general, high levels of grazing are associated with high levels of trampling and high levels of dung production, though some zones may be avoided and some heavily used for defecation.

Vegetation height was also recorded to gain data on the range of heights of vegetation in which the plant could survive, i.e. to characterise the habitat of the species.

In agricultural swards, height is recorded by taking measurements either of single leaves or of the whole sward i.e. the vegetation, ('t Mannetje 1978). The swards encountered in the immediate vicinity of *Spiranthes romanzoffiana* plants, or their previously recorded positions, all exhibited considerable variation in height. Hence a system was devised to accommodate this feature. This involved firstly taking ten height measurements at a sampling station e.g. the sward around the position of a plant and then selecting the median value of this single sample (first order median). The process was then repeated for every sampling station. From this set of values a second order median was obtained which characterised the site as a whole. Different configurations of sampling stations were used, depending on the nature of the site. Further details of this topic and other aspects of the measurement of vegetation height are provided in Appendix C.

Vegetation height was measured to the point where the density of the component stems and leaves of the sward diminished appreciably, as used in the former (pre 1973) Nature Conservancy's Meadow Grassland Survey, (the late Mr Derek Wells, *pers. comm.*). This point is frequently at about 66% of the height of the longest leaf or stem. The height of plants or small stands of *Juncus acutiflorus x articulatus* and *Juncus articulatus* was measured not to the top of the tallest stem but to the point where stems and leaves became less dense.

Vegetation height was recorded in 5mm steps between 10 and 30mm and in 10mm steps thereafter. The height of plants and small stands of *Juncus acutiflorus x articulatus* and *Juncus articulatus* was measured in 20mm steps.

Where there were clearly different layers within the vegetation, these were measured separately. For example at one sampling station one might encounter a low grass and sedge rich, well-grazed i.e. first layer e.g. see Figure A1, a taller, lightly-grazed layer of *Juncus acutiflorus x articulatus* (*Juncus surrejanus*) and an ungrazed layer of *Juncus effusus*.

At site KA and BB subsite A vegetation height was measured at the position of 164 and 44 plants in 2002. Height at a sample of 30 and 38 respectively at the same positions was recorded in 2003, constituting paired data in time.

The occurrence of the taxa in the *Juncus acutiflorus x articulatus/Juncus articulatus* group was investigated at four sites. Records were made of the presence of *Juncus acutiflorus x articulatus* and/or *Juncus articulatus* in a 10x10 cm square centred on the position of a *Spiranthes romanzoffiana* plant at site KA (sample of 120) and KB (sample of 101) on 3 - 7 October 2001. The number of 10x10cm subdivisions that were occupied by *Juncus articulatus* and/or *Juncus acutiflorus x articulatus* in a 50x50cm quadrat which was centred on the stem of *Spiranthes romanzoffiana* was recorded in a sample of 13 at the unmonitored site TG on Colonsay.

Capsules

The nature of the capsules of *Spiranthes romanzoffiana* was examined at the August, September and October visits. Five plants of *Spiranthes spiralis* in fruit were examined in Cumbria, England on 28 October 2002. Plants at the same site were photographed on 18 October 2002 by Mr David Benham.

RESULTS

Population sizes

A standard method in plant surveying involves a count of inflorescences on a single visit per year. Single visit data are presented in Table 1. In Table 1 'Flowering plants' includes those with stems partly grazed or grazed to ground level but still discernable.

The number of plants with stems on 8 August 2002 and on 27 - 29 July 2003 at site KC was 1, 1 and at site LF was 3, 1 respectively. The number of plants in all three states (vegetative, flowering and bud-only) from the 'monitored set' for 2002 and 2003 for KC was 11 and 14 and for LF was 22 and 17. Furthermore at LF on 27 May 2003 26 plants (from the 'monitored set' of 37) were recorded. The number of buds on 23-24 September 2003 at sites KC and LF was 13 and 20 respectively. Thus the count of plants in bloom was small in two populations which actually contained a moderate number of plants.

The presence of 11 plants in 2002 in the set of 18 monitored positions at KC and 14 in 2003 demonstrates the tolerance of the species to heavy grazing regimes producing low swards, (see section 'habitat characterisation').

The number and percentage of flowering plants at new positions is shown in Table 1. In 1999 all the plants at site KB, KC, LF and SF were detected from the presence of flowering stems and this was the case for 49 of the 54 plants at KA. As this was the first year of recording all were 'new' plants i.e. at previously unknown positions. For 2000 and 2001 known positions include vegetative, flowering and bud-only plants. Active searching for and recording of vegetative and bud-only plants ceased in 2001. Thereafter only plants which flowered in a previous year were added to the set which was used to determine if a plant in bloom was a new plant or not. Hence the number of plants added each year to the cumulative total from 1999 will be less in the post 2001 system. This change is indicated by the superscript b in Table 1.

The percentage of new flowering plants falls over the first three years at all sites except KC. This fall in the early years is a consequence of the methodology. Thereafter the percentage remains high at sites KA and KB with summer grazing breaks, and low at KC with no summer grazing breaks in 2001, 2002 and 2003. The percentage is also low from 2002 onwards at LF with light grazing levels.

Using only values of flowering plants from a single annual visit, the cumulative number of records rises progressively from 1999 to 2003 at sites KA and KB, (Table 1). At least one pair of twin mature plants occurred at each of the five sites.

During the period 1999 - 2001 the cumulative number recorded over all visits *within one year*, in all above-ground states (vegetative, flowering and bud-only), rose at all sites, (Table 1). An extrapolation of these trends would suggest that at all sites populations exist which are larger than the all-visits-within-year figure for 2001. This is highly likely to be the case for KA, with values of 122, and 37 new flowering plants for 2002 and 2003; and for KB with 41 and 20 (single visit data, Table 1). The fact that plants can spend up to six years in the underground state indicates that individuals can be quite long lived.

The status of the lowest stem leaf

Table 2 shows the incidence of slug and vertebrate grazing at the leaf at the base of the stem at three sites in August 2002. The high incidence of vertebrate truncated leaves at the two exclosures is due to grazing in the spring prior to the gates being closed. At this time the upper part of these leaf blades were above ground, but the stems and inflorescences (sheathed in bracts) were below ground. On Barra at site BB subsite A the level of winter and spring grazing was less and this is reflected in a low percentage of vertebrate grazed leaves (18%), conversely the level of slug grazing is higher (34%) than that at the other two sites.

The maximal number of leaves per plant occurs when the stem is fully developed. However the upper stem leaves are only exposed to grazing when

the stem attains its full length. The leaves which ultimately become the lower stem leaves appear above ground before the stem itself. The results suggest that the status of the lower stem leaves may be used as an index of spring grazing levels, especially at sites with a summer grazing break i.e. where the stem is not subject to heavy grazing by stock.

Grazing on stems

Sites/years with a summer grazing break

Within the exclosure at site KA the number of flowering stems bearing inflorescences in a sample of 21 on 18 July 2001 declined progressively; 10 being present on 7 August, 4 on 14 August, 1 on 22 August and 0 on 2 September. These plants were located adjacent to a rabbit (*Oryctolagus cuniculus*) burrow and rabbit grazing is assumed to be the cause of the loss of stems.

At site KC in 2000 stock were absent from 1 June to 4 August. One plant was in bloom on 3 July, the flowering stem had been grazed by 17 July, i.e. before the stock were re-introduced. Five further plants were in bloom on 26 July. By 14 August the original plant had its stem grazed right down and one plant had no stem left. By 31 August two had truncated stems, one had the only two basal leaves visible and for three there was no trace of the above ground parts of the plant.

Sites/years with no summer grazing break

In 2001 site KC was subject to more or less continuous grazing, Appendix A. The balance of intact to partly or wholly grazed or trampled flowering stems changed from 7:2 on 18 July to 3:6 on 29 July and 0:9 on 7 August. The values include a diminutive flowering stem and proto-inflorescence only 14mm tall in total, present on 29 July but grazed by 7 August. On the 27 August there was no trace of the above ground parts of one of the plants.

In 2002 and 2003 at KC the stem present had been grazed by the time of the late July/early August visit (Table 1).

General

The results from site KC emphasise the importance of regular recording and of the use of marker pegs without which the basal leaves and the remaining base of the stems (when present) might not have been observed.

At many sites/subsites, on five Hebridean islands, individual stems have been located that have been cut through in the irregular manner associated with slugs (members of the order Stylommatophora); and slugs have sometimes been observed on the stems themselves.

Habitat characterisation

Spiranthes romanzoffiana plants in bloom were found at a wide range of vegetation heights, Table 3. Of special importance are the results from within the exclosures at sites KA (n=164) and KB (n=56) on Colonsay on 9 - 13 August 2002. The populations at these two sites were ungrazed for June, July and part or all of August from 1996 onwards (details in Appendix A): and hence members of the two populations had survived over a number of years in conditions in the summer months broadly similar to those present in 2002. The values refer to the grass and sedge rich i.e. first vegetational layer and exclude the *Juncus articulatus* and *Juncus acutiflorus x articulatus* layer.

At site KC the sward height around the *positions* of 18 members of the monitored set on 8 August 2002 was low, median 25mm; mean value 24mm, and uniform, Coefficient of Variation 17%, (Table 3). No species of the genus *Juncus* were present, although the site is wet during the winter months, their absence apparently being due to the high level of grazing. KC is subject to the same grazing regime as the outside of the exclosures at KA and KB, Appendix A.

Site BB subsite A on Barra has no summer grazing and light to moderate winter grazing. As at sites KA and KB (within the exclosures) *Spiranthes romanzoffiana* was found at a wide range of vegetation heights, the median and mean heights being 70mm and 84mm respectively, (Table 3).

Site LF was lightly grazed in 2002; the mean and median vegetation heights in August 2002 are actually greater than those within the exclosures, ungrazed in June, July and August, (Table 3).

Vegetation height and height of *Juncus articulatus* and *J. acutiflorus* x *articulatus* in 2002 and 2003 at the positions of *Spiranthes romanzoffiana* plants at sites with a summer grazing break.

For measurements paired in time, the vegetation height at the positions of *Spiranthes romanzoffiana* plants at BB subsite A and KA was very highly significantly lower in 2003 than in 2002, (Table 4).

For the non paired measurements the vegetation height (of the grass and sedge rich layer) at the positions of *Spiranthes romanzoffiana* plants in the exclosures at KA and KB was not significantly lower in 2003 than in 2002, (Table 4). In these two cases the vegetation height at the positions of all detected *Spiranthes romanzoffiana* plants in bloom in the relevant year was recorded; (in 2002 n=164 for KA, n= 56 for KB; in 2003 n=57 for KA, n=24 for KB: exclosures ungrazed by stock).

The height of *Juncus articulatus* and *J. acutiflorus* x *articulatus* plants up to the point where the stem and leaves become less dense was highly significantly less for KA in 2003 and very highly significantly less for KB in 2003, non paired data, (Table 4).

The dry summer of 2003 appears to be linked to the lower vegetation height at BB subsite A and KA for paired data: and for heights of *Juncus articulatus* and *J. acutiflorus* x *articulatus* at KA and KB, Table 4. Conceivably it is partly responsible for the lower number of plants in bloom at these three sites in 2003 compared with 2002, (Tables 1 and 4).

Juncus articulatus* and *Juncus acutiflorus x articulatus

There was a 60% frequency of *Juncus articulatus* and/or *Juncus acutiflorus x articulatus* in 10x10cm quadrats at KA; and a lower frequency (28%) at KB: the presence/absence ratios being very highly significantly associated with site, Chi = 23.21, 1 df. (Table 3). As indicated by number of plants in bloom the population of *Spiranthes romanzoffiana* at KA is larger than at KB, (e.g. 164 inflorescences at KA on 9-12 August 2002; 56 at KB, Tables 1, 3 and 4). These two *Juncus* taxa are absent from the nearby site KC. Both taxa were present at the whole site level at KA, KB, LF and also BB subsite A (Table 3). Both taxa occur at exclosure site ten Gulliver *et al.* (2004b, this volume) on the margins of the diffuse site SF. Further studies on the balance of this these two taxa on a quadrat basis at ten exclosure sites are presented in Gulliver *et al.* (2004b, this volume).

At the unmonitored site TG on Colonsay the median number of 10x10cm subdivisions in a 50x50cm quadrat that were occupied by *Juncus articulatus* and/or *Juncus acutiflorus x articulatus* was 12, the range being 1 to 22. The quadrat was centred on the stems of 13 *Spiranthes romanzoffiana* plants on 19 September 2001. The cumulative number of plants that flowered at TG in 2001 was 33. Site TG is summer and winter grazed.

There are no obvious indications that the observed plants of *Spiranthes romanzoffiana* are being adversely affected by the two *Juncus* taxa, but only long-term studies will determine the matter absolutely.

The samples taken at site KB on 7 October 2001 which had been ungrazed since 30 May included an example of *Juncus articulatus* (with capsules) that was 9cm tall and an example of *Juncus acutiflorus x articulatus* (with capsules) that was 10cm tall; these dwarf plants representing one end of the great range of variation in size that can occur in the two taxa.

The current authors found *Juncus acutiflorus x articulatus* at the two *Spiranthes romanzoffiana* sites where they carefully examined the *Juncus* species on Coll. Henderson (2001) reported a 20% frequency of the taxon that she recorded as *Juncus articulatus* at 81 10x10 cm sampling stations centred on *Spiranthes romanzoffiana* plants on Coll. Pearman and Preston (2001) do not record *Juncus acutiflorus x articulatus* from Coll. Rich and Jermy (1998) describe *Juncus acutiflorus x articulatus* as 'probably under-recorded'.

Changes in vegetation height over time

Table 5 shows the change in vegetation height over time for the five sites including the paired values on each side of the exclosure fence at sites KA and KB in 2001. In 2001 sheep and cattle were excluded from 30 May onwards at KA and KB, and hence no separate inside values for 16 May 2001 were recorded. 18 - 20 September 2002 values are also presented. The low May values indicate the intensity of winter and early spring grazing.

For site KA wet and dry the ungrazed height values increase progressively from June to October. Maximum values are shown in bold in Table 5. The nature of the grazed wet sward at KA on 19 September 2002 is shown in Figure A5. The measured i.e. first vegetation layer on the ungrazed side is masked by *Juncus* spp. (mainly *Juncus acutiflorus* x *articulatus*) plants, which appear to be more dense on the photograph than is the case on the ground. For site KB dry ungrazed a peak is reached in mid-late August with declining values thereafter. For KB wet ungrazed there is a peak in early August with lower but somewhat erratic values thereafter. Further aspects of vegetation height and its ecological significance at sites KA and KB are presented in Appendix C.

Site KC, was more or less continuously grazed in 2001 and 2002 (see Appendix A and B) by the same stock as the outside sward of KA and KB and the height values are similar to the dry outside values at KA and KB. On the visit to KC in July 2003 tillers of *Molinia caerulea* and *Nardus stricta* and parts of *Calluna vulgaris* plants were seen on the ground, apparently having been pulled up by stock. Dead tillers of *Molinia caerulea* had also been seen on the sward surface on previous visits.

Site LF was lightly and intermittently grazed in 2001 and 2002 (see Appendix B) and its vegetation height values resemble the inside wet and dry swards of KA, but with a drop in September 2001 due to grazing which commenced on 29 August 2001.

Site SF was grazed more or less continuously, but with varying intensities. The moderately high vegetation height indicates that the plant stations studied were grazed to an intermediate level of intensity.

Vegetation height will vary with factors which change throughout the season. These include the rate of growth of the sward, changing palatability of plant species present, the intensity of grazing due to varying numbers of stock, and stock preferences for particular zones within the grazed area.

Vegetational height will be affected by local differences in soil conditions within the total area, these differences become fully expressed in the absence of grazing. The vegetation height for the dry section of KB ungrazed is consistently lower than the wet section. However the dry and wet sections of KA are similar. Differences within the wetness category are shown by comparisons of KA ungrazed with KB ungrazed. The KA dry values are considerably higher than the KB dry values. Similarly the KA wet values are considerably higher than the KB wet ones.

Observations on *Spiranthes romanzoffiana* and *Spiranthes spiralis* plants in August, September and October

Fully-developed, dry capsules with longitudinal slits have not been observed by any of the authors in the study period, 1999 - 2003; e.g. during the survey on 3 to 5 Oetober 2001 of the 39 plants with surviving stems at KA and the 19 at KB in 2001, Gulliver (2002). The observed eourse of development is always that the capsules develop part way and then become flaccid, turning from green to brown and then shrivel.

The capsules of *Spiranthes spiralis* dry in the fully expanded state in Cumbria, see Figure A6 (photograph kindly supplied by Mr David Benham). The shrivelled capsules of *Spiranthes romanzoffiana* of plant A4 at site GF on Coll on 1 October 2002 are shown in Figure A3 (photograph kindly supplied by Ms Emma Grant); and in Figure 1C in Gulliver *et al.* (2000) for plant 2 from site LF on Colonsay on 15 September 99.

It was therefore not possible to examine the performance of plants of *Spiranthes romanzoffiana* in swards and grazing regimes of different types by comparing aspects of sexual reproductive output at different locations. This technique was used by Legg, Cowie and Sydes (1997) who showed a 49% loss of scapes to sheep and rabbit grazing in *Primula scotica* in 1993 and a 42% loss in 1994 using caged plots.

Our observations are confined to the state of the capsules. They do appear to lend support to the experiences of Robarts (2000) who states 'I have however yet to be convinced that *Spiranthes romanzoffiana* in Barra is in fact setting seed'.

DISCUSSION

Detection of populations

The existence of a summer grazing break allows *Spiranthes romanzoffiana* plants to flower and hence their presence to be detected. The number of plants observed in bloom at sites KA and KB has risen from the values of 49 and 24 in 1999, (Table 1, single visit data) to 164 and 56 respectively in 2002. In 2003 the values were 57 and 24, (Table 1). At both sites new plants represented 65% or over of the plants in bloom, 1999 to 2003.

At sites KC and LF, with no exclosures, the number of plants in bloom in 2002 were 1 and 3 and in 2003 1 and 1. Nevertheless the numbers present at the 'monitored set' of positions for 2002 were 11 at KC and 22 at LF; and for 2003 were 14 for KC and 17 for LF. At these two sites moderate-sized populations were in existence, despite the very low numbers of plants in bloom. Thus number of inflorescences is not always a useful guide to population size.

Even with a summer grazing break, number of plants in bloom can vary greatly. Forty-four were in flower at BB subsite A in 2002, five in 2003, single visit data, (Table 4).

Reproduction

The non-production of expanded capsules on any of the plants examined at the reference sites emphasises the need for more investigation on the presence and extent of sexual and vegetative reproduction in the species, ideally under both natural and controlled conditions.

Habitat characterisation, vegetation height, effects of stock presence

The survival of plants at a range of vegetation heights, measured in August 2002, indicates that the individuals of *Spiranthes romanzoffiana* exhibit a fairly broad band of tolerance with regard to this habitat characteristic. The populations at sites KA (n=164) and KB (n=56) had been ungrazed for June, July and part or all of August from 1996 to 2002 (for details see Appendix A: from 2001 the exclosure plots were established). Thus there has been a seven-year period for competitive interactions between species to exert their influence. The results from site BB subsite A, subject to more or less the same grazing regime every year, show the same trend, (Table 3).

Spiranthes romanzoffiana populations also exist at a range of vegetation heights at sites with no summer grazing break, e.g. site LF.

The survival of the moderate-sized population at Site KC indicates the potential of the species to tolerate regimes of more or less continuous grazing producing low, uniform swards, at some sites at least. The number of buds on 23 September 2003 in the monitored set of positions at site KC was 13, suggesting a continuation of population of a similar size in 2004.

Differences in vegetation height on either side of exclosures against summer grazing at heavily grazed sites reveal the impact of the grazing process and provide an index of the potential biomass in the absence of grazing.

Continuous grazing is inevitably associated with continuous trampling and defecation activity. The possible positive, negative or neutral effects of these two features of stock presence have yet to be investigated.

Defoliation results in loss of the photosynthetic tissues, but potential competitors may also be affected. Trampling will result in tissue damage but may also result in root fracture which could conceivably be a form of vegetative reproduction in the Orchidaceae (Rasmussen, 1995, p.129); furthermore in marshy areas, patches with high levels of light penetration are created as small pieces of vegetated sod are pushed into the substrate. Dung deposition by cattle will result in the total loss of light to the plant for a period. However the organic carbon source from cattle and sheep dung may well ultimately be of importance to the fungal associate. It would be possible to study all these topics in the field; but more precise results would be obtained from controlled experimental manipulations in botanic gardens, if material were

available and the relevant conservation organisations approved such a course of action.

Many *Spiranthes romanzoffiana* sites in Scotland are beside lochs, and the plant may obtain temporary relief from grazing during periods of high water following heavy summer rains. Grazing at such locations during dryer periods may ensure general habitat suitability for *Spiranthes romanzoffiana*. At the smaller subsite of LF, near the loch; three individuals were under water on 15 September 1999, but all produced vegetative plants in 2000.

Several of the Irish lough-side sites are ungrazed or very lightly grazed F. Horsman, D. Lupton, N. Kingston; (*pers. comm.*). Hence there may be factors other than grazing at such sites which are advantageous to the species, e.g. the perturbation of the marginal zone by wave action and/or the deposition of silt and humus during periods of high water levels.

Juncus articulatus* and *Juncus acutiflorus x articulatus

Plants of *Spiranthes romanzoffiana* can occur growing with stems of *Juncus articulatus* and/or *Juncus acutiflorus x articulatus*, e.g. see Tables 3 and 4. At sites which are not heavily grazed they appear to gain a measure of protection from consumption by the presence of these less palatable (but not inedible) plants. The long-term fate of *Spiranthes romanzoffiana* individuals growing in stands of *Juncus articulatus* and/or *Juncus acutiflorus x articulatus* is yet to be investigated.

Recording site conditions and the longevity of *Spiranthes romanzoffiana*

For any given study site stock may be moved on and off at regular or irregular intervals or very rarely moved; and the number of livestock plus the balance of species of livestock may change over time. In addition perceived management objectives may alter; and sites may be subdivided by fencing or expanded by allowing access through gates, or by fences becoming functionless. The position of temporary features e.g. winter feeding stations may vary from week to week or year to year or be constant. Furthermore sand blow, fire, local flooding and draining activities plus other site-specific biotic or abiotic factors may affect vegetation and patterns of grazing. All these changes may have conservation significance and it is important to record them. Only with these data can one interpret population changes. Appendix A is an example of the presentation, in table format, of changes to some aspects of site conditions for a ten-year period. Future ecological analysis requires extensive records, however such detailed data may be difficult to condense and present in a meaningful summary form.

The fact that *Spiranthes romanzoffiana* can occur in the underground form for up to six complete years (Dr James Robarts, *pers. comm.*) makes long-term study of both the species and its environment especially important, i.e. seven years must elapse after the initial observation before one can assume that a plant at a marked position has died.

Monitoring populations

Fully developed capsules have not yet been observed in Scotland. Six populations (B-G) of marked individual plants on Barra have been monitored by Dr James Robarts since 1993 and one (A) since 1992, e.g. see Gulliver (2002); and populations of unmarked plants have been studied since 1988 (Robarts 2000).

One subsite of site WC on Coll has supported plants since 1978 (Ferreira 1978 record in Scottish Natural Heritage files and current authors' visits of 2000 and 2001). It therefore seems likely that vegetative reproduction may be very important for the maintenance of populations of the species. Other rare species maintained wholly or largely on vegetative reproduction in Scotland are *Carex chordorrhiza* and *Saxifraga hirculus* (Legg, Cowie and Sydes 1997); together with *Linnaea borealis*, *Cicerbita alpina* and *Saxifraga cernua* (Wilcock 2002).

The current studies reveal an absence of any annual, readily-quantifiable measure of sexual reproductive output, e.g. the number of mature capsules. (If present measurements of the total weight of fully developed seeds per capsule; or an estimate of total number of seeds based on samples from different parts of the ovary wall; would ideally additionally be recorded). Therefore other measures will have to be used to investigate yearly performance and importance or otherwise of intensity of grazing. These include recording the expansion or contraction of population size, once the majority of existing plants have been recognised. Such a technique requires a very long period of monitoring of permanently marked and mapped plants. This approach has been developed to a high degree by Dr James Robarts on Barra (Robarts 2000; and the analyses of Dr Robarts' data 1992-2001 in Gulliver (2002) for the seven populations (A-G) which have a summer grazing break and light winter grazing and the two which have some grazing summer and winter (H-I).

The technique accommodates scenarios where the populations never produce seed; only produce seed occasionally; where fertility barriers exist which vary in their effectiveness from year to year; and where heavy grazing results in the high or total loss of inflorescences. It could therefore be very usefully applied to study the variation in population performance e.g. at sites subject to different grazing regimes. Ideally the sites should be ones where the full range of abiotic and biotic factors present are also being recorded

ACKNOWLEDGEMENTS

Kind thanks are extended to following organisations, individuals and funding bodies.

The owners, farmers and crofters of the sites for permission to make these observations; the staff of the Scottish Natural Heritage offices at Islay, and South Uist; and the Enquiry Service of English Nature and Publications Section of Scottish Natural Heritage.

Dr James Robarts and Dr Frank Horsman for sharing their experience of the species. Mr David Benham, Dr Neil Cowie, Professor Michael Crawley, Dr Mike Dodd, Mr Alan Forrest, Ms Verena Forster, Dr Mark Gardener, Ms Emma Grant, Mr Nigel Grant, Dr Mark Hill, Dr Naomi Kingston, Dr Marilyn Light, Mr Alex Lockton, Mr Darach Lupton, Ms Rae McKenzie, Mr John McKinnell, Mrs Wendy Nelson, Mr Philip Oswald, Professor Clive Stace, Dr Robin Sutton and Dr Christopher Wilcock.

Scottish Natural Heritage for funding the two research projects and the Botanical Research Fund. The administrators of the Professor Blodwen Lloyd Binns Bequest for a grant towards attendance at a British Ecological Society conference at which results of the investigations were displayed.

REFERENCES

Bowler, J. (2003) Irish Lady's-tresses (*Spiranthes romanzoffiana*) discovered on the Isle of Tiree, Argyll. *BSBI News - the newsletter of the Botanical Society of the British Isles* 92, 25-26.

Blackstock, T.H. and Roberts, R.H. (1986) Observations on the morphology and fertility of *Juncus* x *surrejanus* Druce ex Stace & Labinon in north-western Wales. *Watsonia* 16, 55-63.

Cheffings, C. (2004) New plant status lists for Great Britain. *BSBI News - the newsletter of the Botanical Society of the British Isles* 95, 36-43.

Diack, I.A., Burke, M., and Peel, S. (2000) Grassland management for nature conservation: towards a consistent approach to sward measurement and description. Pp. 155-156 in Rook, A. J. and Penning, P.D. (editors.) *Grazing Management* - British Grassland Society symposium No. 34. British Grassland Society, Reading, Berkshire:.

Forrest, A. (2001) *Genetic structure within and among populations of* Spiranthes romanzoffiana *Cham. in Scotland.* M.Sc. Thesis. Royal Botanic Garden Edinburgh and University of Edinburgh.

Forrest, A.D., Hollingsworth, M.L., Hollingsworth, P.M, Sydes, C., and Bateman, R.M. (2004) Population genetic structure in European populations of *Spiranthes romanzoffiana* set in the context of other genetic studies on orchids. *Heredity* 92, 218-227.

Grime, J.P., Hodgson, J.G. and Hunt R. (1986) *Comparative plant ecology: a functional approach to common British species.* Unwin Hymen, London

Gulliver, R.L. (1996) The status of *Spiranthes romanzoffiana* Cham. (Orchidaceae) Irish Lady's Tresses, on Colonsay, (v.c. 102) in 1995; with special reference to associated plant communities. *Watsonia* 21 (2), 202-204.

Gulliver, R.L. (1997) Irish Lady's Tresses (*Spiranthes romanzoffiana)* on Colonsay, (VC 102). *The Glasgow Naturalist* 23 (2), 55-56. Plus brief note in *The Glasgow Naturalist* 23 (3), 77.

Gulliver R.L. (2002). *Dr Richard Gulliver action plan research into the ecology of* Spiranthes romanzoffiana *in Scotland.* viii & 124pp. Unpublished report to Scottish Natural Heritage.

Gulliver, R., Gulliver, M., Keirnen, M., and Sydes, C. (2004b). Studies on the conservation biology of Irish lady's-tresses orchid, *Spiranthes romanzoffiana* 2) The establishment of 10 exclosures, dung counts and further studies on associated *Juncus* taxa (species and hybrid rushes). *The Glasgow Naturalist*. Current volume.

Gulliver, R.L., Gulliver, M. and Sydes, C. (2003) The relationship of a Biodiversity Action Plan (BAP) orchid, *Spiranthes romanzoffiana*, to grazing in the West of Scotland. Aspects of Applied Biology 70: *Crop quality: its role in sustainable livestock production*. Published by the Association of Applied Biologists c/o Horticulture Research International, Wellesbourne, Warwick CV35 9EF, UK. (This conference had a section on biodiversity) pp. 143-150.

Gulliver, R., Keirnen, M., Gulliver, M. and Sydes, C. (2000) Observations on Irish lady's-tresses orchid (*Spiranthes romanzoffiana*) on Colonsay (vc102). *The Glasgow Naturalist* 23 (5), 9 -12.

Henderson, S.A. (2001) The vegetation associated with *Spiranthes romanzoffiana* Cham. (Orchidaceae), Irish Lady's-tresses, on the Isle of Coll, Inner Hebrides. *Watsonia* 23, 493-503.

Legg, C., Cowie, N., and Sydes, C. (1997) The importance of regeneration studies to successful conservation management of Scottish rare plants. *Botanical Journal of Scotland* 49, 425-432.

MacDonald, A., Stevens, P., Armstrong, H., Immirzi, P., and Reynolds, P. (1998a) *A guide to upland habitats: Surveying land management impacts. Volume 1. Background information and guidance for surveyors.* Scottish Natural Heritage, Edinburgh.

MacDonald, A., Stevens, P., Armstrong, H., Immirzi, P., and Reynolds, P. (1998b) *A guide to upland habitats: Surveying land management impacts. Volume 2. The field guide.* Scottish Natural Heritage, Edinburgh.

t' Mannetje, L. (1987) (editor) *Measurement of grassland vegetation and animal production.* Commonwealth Bureau of Pastures and Field Crops, Hurley, Berkshire.

Pearman, D.A., and Preston, C.D. (2001) *A flora of Tiree, Gunna and Coll.* Privately published by the authors, Dorchester.

Preston, C.D., Pearman, D.A. and Dines, T.D. (2002) *New Atlas of the British and Irish Flora.* Oxford University Press, Oxford.

Rich, T.C.G. and Jermy, A.C. (1998) *Plant Crib 1998.* Botanical Society of the British Isles, London.

Robarts, J. (2000) A study of the orchid *Spiranthes romanzoffiana* on the island of Barra. *Hebridean Naturalist* 13, 30-35.

Rasmussen, H.N. 1995. *Terrestrial Orchids from Seed to Mycotrophic Plant.* Cambridge University Press, Cambridge.

Roberston H.J. and Jefferson R.G., (2000) *Monitoring the condition of lowland grassland SSSIs. I English Natures's rapid assessment method.* English Nature, Research Report No. 315, Peterborough.

Stace, C.A. (1997) *New Flora of British Isles, Second Edition.* Cambridge University Press, Cambridge.

Stewart, A., Pearman, D.A. and Preston, C.D. (eds.) (1994*) Scarce plants in Britain.* Joint Nature Conservation Committee, London.

Stewart, K.E.J., Bourn, N.A.D. and Thomas, J.A. (2001) An evaluation of three quick methods commonly used to assess sward height in ecology. *Journal of Applied Ecology* 38, 1148-1154.

UK Biodiversity Action Group (1999) *Tranche 2 Action Plans Volume 3. Plants and fungi.* English Nature, Peterborough.

Wilcock, C.C. (2002) Maintenance and recovery of rare clonal plants: the case study of the twin flower (*Linnaea borealis*). *Botanical Journal of Scotland* 54, 121-130.

Table 1. Number of flowering plants (see general note) of *Spiranthes romanzoffiana* recorded on a single summer visit and the number and percentage which had not previously been recorded as flowering (F) and vegetative (V) and bud-only (B) plants for 1999 to 2003; plus cumulative number of V, F and B plants recorded over all visits in any one year for 1999, 2000 and 2001; on Colonsay.

		Single yearly visit data - F plants					**Multiple visit data F, V and B plants**	
Site letter code and number	Summer grazing break see Appendix A	Date of single visit - sometimes each subzone visited sequentially	Number of flowering plants (F) recorded. Max. value in bold	Number F never previously recorded as F, V or B plants.	Percentage F never previously recorded as F, V or B plants.	1999-2003 cumulative number F based only on single visit data	Within year cumulative value flowering, vegetative, & bud-only	Year for cumulative within year visit totals
LF (1)	N	21/08/99	8	8	100	8	8	1999
LF (1)	N	13/08/00	**14**	13	93	21	27	2000
LF (1)	N	04/09/01	8	4	50	25	32 [37[a]]	2001
LF (1)	N	08/08/02	3	1[b]	33[b]	26		
LF (1)	N	27/07/03	1	0[b]	0[b]	26		
KA (2)	Y	14/08/99	49	49	100	49	54	1999
KA (2)	Y	15/08/00	43	38	88	87	127	2000
KA (2)	Y	30/08/-06/09/01	113	76	67	163	213	2001
KA (2)	Y	9-12/08/02	**164**	122[b]	74[b]	285		
KA (2)	Y	28/07/03	57	37[b]	65[b]	322		
KB (3)	Y	14/08/99	24	24	100	24	25	1999
KB (3)	Y	14/08/00	32	31	97	55	86	2000
KB (3)	Y	28/08/01	**67**	53	79	108	142	2001
KB (3)	Y	13/08/02	56	41[b]	73[b]	149		
KB (3)	Y	28/07/03	24	20[b]	83[b]	169		
KC (4)	Y	26/07/99	1	1	100	1	1	1999
KC (4)	Y	14/08/00	5	4	80	5	7	2000
KC (4)	N	26-29/07/01	**9**[c]	8	89	13	17[18[a]]	2001
KC (4)	N	08/08/02	1[d]	0[b]	0[b]	13		
KC (4)	N	29/07/03	1[d]	0[b]	0[b]	13		
SF (5)	N	04/08/99	**3**	3	100	3	3	1999
SF (5)	N	25/07/00	2	1	50	4	4	2000
SF (5)	N	25/07/01	0[e]	0	-	4	6[8[a]]	2001
SF (5)	N	-	Not surveyed[f]		-			
SF (5)	N	-	Not surveyed[f]		-			

Notes

General: 'Flowering plants' include those with stems partly grazed or grazed to ground level but still discernable.

[a] For LF, KC and SF the values in square brackets are the totals of F, V and B plants pooled over all visits in all years, 1999 - 2001, i.e. for LF and KC the subsequently 'monitored set'.

[b] In 2002 and 2003 additions to the cumulative number recorded consist only of plants flowering in that year, recorded on a single visit, i.e. there is an alteration to the basis on which the number and percentage new plants in bloom is calculated.

[c] Includes one miniature plant with diminutive stem and proto-inflorescence, total height 14mm.

[d] Flowering stem grazed a time of late July/early August visit.

[e] One plant was in bloom on 4 September.

[f] An area on the margin of the diffuse site SF with a 1996 plant record became plot ten, Gulliver *et al.* 2004b.

Table 2. The grazed or withered[a] status of the lowest stem leaf in August 2002 at sites KA and KB exclosed since 1 June in 2002; and at Site BB area A; not subject to summer grazing.

Percentages are rounded to the nearest whole number and hence in two cases appear to add up to 101.

	Sites and Dates					
	KA 07-08/08/02		KB 07/08/02		BB subsite A 14/08/02	
Leaf Status	Number	Percentage	Number	Percentage	Number	Percentage
Ungrazed	35	22	19	34	10	23
Vertebrate truncated	100	63	30	54	8	18
Slug truncated and/or damaged	16	10	6	11	15	34
Withered[a]	9	6	1	2	11	25
Total	160[b]		56		44	

Notes

[a] So badly withered that the end of the leaf could not clearly examined or was absent. Slightly withered leaves were allocated to one of the other three categories.

[b] 160 was the count during a general survey on 7-8 August. Between 9-12 August every plant was mapped, and the count was 164, see Table 1.

Table 3. Frequency of values of vegetation height measurements in the vicinity of *Spiranthes romanzoffiana* plants in August 2002 at one site subject to more or less continuous grazing, two exclosed sites, one site with no summer grazing; and one lightly grazed site: plus other sward details. Height values for the layer made up of *Juncus* species, present at some sampling stations at KA, KB and LF, are not included.

Site	**KC**	**KA**	**KB**	**BB sub-site A**	**LF**[a]
Grazed/ Exclosed	Well Grazed	Exclosed	Exclosed	No Summer Grazing	Lightly Grazed[a]
Date	8/8/02	9-12/8/02	13/8/02	14/8/02	8/8/02
Vegetation height of the sward - 5mm steps between 20 and 30mm at KC: 10mm steps at other sites					
Median value shown bold					
20	5				
25	**12**				
30	1	3	0	0	
40		14	0	4	0
50		37	5	14	1
60		**31**	13	2	5
70		30	**17**	**3**	4
80		26	13	4	**10**
90		4	3	2	4
100		10	4	1	2
110		3	0	5	1
120		2	1	2	0
130		2	0	1	0
140		0	0	2	1
150		2	0	1	0
160				1	
170				0	
180				0	
190				2	
Median height	25	60	70	70	80
Mean height	24	67	72	84	80
Coefficient of Variation	11	32	20	49	23
No. of samples	18[b]	164	56	44	28[ab]
Number of plants with flowering stems on date of visit	1[c]	164	56	44	3[a]
% of flowering stems which are newly recorded plants	0	74	73	36	(33)[a]
% occurrence on 3-7/10/01 at sites KA, KB and KC of *Juncus articulatus* and *J. acutiflorus x articulatus* in a 10x10cm square centred on the position of a *Spiranthes romanzoffiana* plant					
Percentage	0	60	29		
No. of sampling stations	18	120	101		
Chi square presence/absence of *Juncus* species for sites KA/KB very highly significant Chi = 21.63, 1 df.					
Presence on entire site (2001 and 2002)					
Juncus articulatus	-	+	+	+	+
Juncus acutiflorus x articulatus	-	+	+	+	+

Notes

[a] Site LF was lightly and intermittently grazed in 2002. The height values refer to main population centred on the five plants first recorded in 1999, (as also in Table 5). In 2002, one plant in bloom in the main population, two in the sub-population. 33% new plants refers to whole site.

[b] For sites KC and LF these are positions of plants recorded 1999 to 2001, not necessarily above ground plants at the time of the height measurements.

[c] Stem was grazed.

Table 4. Vegetation height and height of *Juncus articulatus* and *J. acutiflorus* x *articulatus* at the positions of *Spiranthes romanzoffiana* plants in late July/early August 2002 and 2003 at sites with a summer grazing break.

	2002 Mean	Median	Number of values	Number flowering single date	2003 Mean	Median	Number of values	Number flowering single date	Significance of 2002 to 2003 comparisons (two tailed)
Barra (site BB) and Colonsay (site KA) paired measurements; n is different from number flowering in 2002									
Site BB subsite A 14/8/02 & 8/8/03	81	65	38[a]	44	63	50	38[ab]	5	VHS z=7.37
Site KA 9-12/8/02 & 28/7/03	67	60	30[c]	164	52	50	30[bc]	57	VHS z=3.76
Colonsay non paired measurements; n is both sample size and number flowering (single visit)									
Site KA 9-12/8/02 & 28/7/03	67	60	164[d]	164	67	60	57[d]	57	NS z=0.09
Site KB 13/8/02 & 28/7/03	72	70	56[d]	56	65	60	24[d]	24	NS z=1.55
***Juncus articulatus* and *J. acutiflorus x articulatus* height (see text), Colonsay; non paired measurements** At positions of *Spiranthes romanzoffiana* plants									
	Mean	Median	Sampling stations with *Juncus* spp.	Total number sampling stations	Mean	Median	Sampling stations with *Juncus* spp.	Total number sampling stations	
Site KA 9-12:8:02 & 28:7:03	291	300	[67][e]	[96][e]	242	260	53	57	HS z=3.27
Site KB 13:8:02 & 28:7:03	223	200	27	56	142	140	20	24	VHS z=7.69

Notes
HS Highly Significant, VHS Very Highly Significant, NS Not Significant
a) 31 negative differences, 7 zero differences, 0 positive differences.
i.e. there are no differences in values which run opposite to the main trend.
b) All were at positions of plants in bloom in 2002.
c) 22 negative differences, 3 zero differences, 5 positive differences.
i.e. there were 5 differences which run opposite to the main trend.
d) 100% sampling of plants in bloom in 2003.
e) 96 positions sampled for *Juncus* spp. within entire set of 164 plant stations.

Table 5. Overall median of vegetation heights in mms (maximum values shown bold) between May and October 2001 and on 18-20 September 2002 at two sites with grazed and ungrazed sections and dry and wet parts plus one well-grazed, one lightly grazed and one variably grazed site.

Height values for the layer made up of *Juncus* species, present at some sampling stations at KA, KB, SF and LF, are not included.
NR = Not Recorded

For details of the configuration of the sampling stations see Appendix C

Site	KA dry grazed O (outside) n = 10	KA dry ungrazed I (inside) n = 10	Difference of medians	KB dry grazed O (outside) n = 10	KB dry ungrazed I (inside) n = 10	Difference of medians	KC heavily grazed n = 3/18[a]	LF[b] Lightly grazed n = 10	SF Variable intensities of grazing n = 3
Values for KA dry & KB dry									
2001 (KA & KB dry ungrazed 30 May - 7 October)									
May	15	see O value [0]		10	see O value [0]		15	-	-
mid June	15	25	10	15	25	10	-	-	-
late June	20	35	15	15	28	13	15	-	-
early July	-	-		-	-		-	50	50
mid July	15	48	33	15	38	23	**40**	73	45
early August	28	85	57	25	50	25	30	**100**	**80**
mid-late August	**30**	95	65	**28**	**58**	30	30	90	**80**
early September	25	110	85	23	50	27	25	**100**	55
late September	18	110	92	20	50	30	20	50	-
October	10	**140**	**130**	10	45	**35**	20[a]	-	-
2002 (KA & KB dry ungrazed 1 June - 25 September)									
18-20 September	20	120	100	20	55	35	20	105	NR
Values for KA wet & KB wet							**Day of Month**		
	KA wet grazed O (outside) n = 10	KA wet ungrazed I (inside) n = 10	Difference of medians	KB wet grazed O (outside) n = 10	KB wet ungrazed I (inside) n = 10	Difference of medians	KA/KB /KC see notes c & d	LF	SF
2001 (KA & KB wet ungrazed 30 May - 7 October)									
May	10	see O value [0]		10	see O value [0]		16[c]/6[d]	-	-
mid June	15	33	18	23	35	12	13[c]/ -[d]	-	-
late June	20	53	33	18	45	27	28	-	-
early July	-	-	-	-	-	-	-	5	5
mid July	30	55	25	20	45	25	12	19	18
early August	30	85	55	28	**85**	**57**	7	2	2
mid-late August	35	90	55	**35**	73	38	22	14	14
early September	**38**	95	57	**35**	63	28	6	4	4
late September	28	100	72	30	60	30	20	22	-
October	20	**120**	**100**	20	70	50	6[c]/3[d]	-	-
2002 (KA & KB wet ungrazed 1 June - 25 September)									
18-20 September	25	120	95	30	80	50	18[d]/19[c]	20	20

Notes
[a] Median of 18 sampling points on 3 October, otherwise median of 3 sampling points.
[b] Main subsite.
[c] For KA and KB.
[d] For KC.

Appendix A.

Details of the different management phases at Sites KA[a], KB[a], KC[b] within a dune system (i.e. on the seaward side of the 1996 moor/dune fence) and TG[c] (immediately on the 'moor' side of the 1996 moor/dune fence) on Colonsay from 1991 (when observations by RG and MG began) to 2003.

See Appendix B for further site details

Year or period	Phase 1 signifies more or less continuous grazing, 2 signifies a summer grazing break	Sites affected	Period of grazing by sheep and cattle	Period of summer grazing break
1991 - 1995 - No moor/dune fence, no summer grazing break				
1991 - 1995	Phase 1A	KA, KB, KC, TG	more or less continuous[d]	none
1996 - Moor/dune fence established, with gates				
1996 - 1999	Phase 2A	KA, KB, KC	15 August - 31 May (following year)	31 May - 15 August
1996 - 1999	Phase 1B Similar to 1A but with the moor/dune fence and gates, hence stock either a) all on the moor or b) all on the dunes or c) in both areas	TG	more or less continuous[d]	none
2000	Transition Phase	KA, KB, KC	up to 31 May 2000, more or less continuous after 4 August 2000	31 May - 4 August
2000	Phase 1B	TG	more or less continuous[d]	none
2001 - Exclosures[e] at KA and KB established in the spring				
2001, 2002 & 2003	Phase 2B similar to Phase 2A but with a longer summer grazing break	KA, KB	up to late May/early June and after late September/early October	From late May/early June to late September/ early October
2001, 2002 & 2003	Phase 1B	KC	more or less continuous[d]; grazing heaviest when all stock are on the dunes only (for conservation management for chough) i.e. when moor /dune gates are shut and stock are on the seaward side	none
2001, 2002 & 2003	Phase 1B	TG	more or less continuous[d] but with no grazing when all stock are on the dunes only (for conservation management for chough)	none

Notes

General: The exclosures have 6 sides at site KA and 5 at KB and are irregular in shape.

[a] Sites KA and KB are in zones within the dunes which are wet partly due to the impervious nature of the underlying rock, see also Appendix B.

[b] Sites KC is on a slope, but the sandy substratum is periodically wet, especially in the winter.

[c] Site TG is in damp gully with a burn in the zone between moorland and dunes; the substrate includes windblown sand.

[d] With some breaks e.g. when sheep are dipped

[e] Some plants occur outside the fence at sites KA and KB. Of the 49 and 25 plants recorded in bloom in 1999 at KA and KB (all visits), one is outside the 2001 exclosure at KA and one at KB.

Appendix B. Characteristics of the study sites.

Slug activity has been recorded from all sites

Site code	Site number used in Gulliver *et al.* 2000	Site Unenclosed (extensive) =UE or Enclosed (a field) =E	Grazing vertebrate. Most abundant first	Summer grazing break	Adjudged intensity of grazing [a]	Slope. Different zones may have different characteristics
Colonsay						
LF	1	E[b]	C & S, R, G	N	L	F
KA	2	UE	S & C, R	Y	H	F, GS
KB	3	UE	S & C, R	Y	H	VGS
KC	4	UE	S & C, R	Y/N [c]	H	MS
SF	5	UE	S & C, R	N	V	F (mainly) VGS (in part)
TG	-	UE	S & C, R	N	M (V)	BSG
Barra						
BB / A		UE	C & S	Y	L	F

Wetness	
LF	Adjacent to loch
KA	Wet in part, dry in part. Pegs and plants may be pushed deep down into the substrate in the marshy parts by stock
KB	Centre of the very shallow hollow is wet, very slight downslope water movement
KC	Some downslope water movement in winter
SF	Mainly next to a burn; part of site slopes gently to burn
TG	Gully bottom wet, burn present, sides dampish due to impeded drainage
BB / A	Surface water movement in wet periods

Abbreviations: The code for the most abundant animal is always presented first.
BSG = Bottom and sides of a gully, C = Cattle, E = Enclosed site (field), F = Flat, G = Geese,
GS = Gentle Slope, H = Heavy, L = Light, M = Moderate, MS = Moderate slope, N = No, R = Rabbit,
S = Sheep, UE = Unenclosed (extensive), V = Variable, VGS = Very gentle slope, Y = Yes

Notes
General: Further details in Gulliver (2002).
[a] And associated animal activity e.g. trampling and defecation.
[b] Whole field very approximately 3 ha in extent.
[c] Summer grazing break in 1999 and 2000 not in 2001 and subsequently.

Appendix C. Vegetation height: further details.

Aspect of the definition

The definition of vegetation height utilised herein i.e. to the point where the density of the component stems and leaves of the sward diminished appreciably, is very similar to the one used by English Nature to assess the status (e.g. conditions favourable/unfavourable) of Sites of Scientific Interest (Robertson and Jefferson, 2000), in which height is 'assessed as the average height rather than the extreme of flowering spikes of grasses and tall herbs'.

Devices used to measure vegetation height

Trials were conducted on Colonsay on the measurement of height using a 10cm sward disc, also known as a sward plate, (Diack, Burke and Peel, 2000). The presence of many ungrazed and grazed stems of *Juncus* spp. caused the plate to lie at an angle or raised it above the main sward surface, and so the technique was not used subsequently.
Investigations on the relative merits of direct measurements of vegetational height (as used in this study), use of a sward disc of 30cm diameter (both 10 and 30 cm discs are in current use) and the Hill Farming Research Organisation's sward stick, carried out on chalk grassland in southern England, are reported in Stewart *et al.* (2001). Each has certain advantages and certain demerits, the direct measurement technique was found to be less strongly affected by vegetation structure than the other two systems.

Configuration of samples

KA and KB 2001 and 2002, wet and dry; n = 10; arrangement - linear - details as text below
KC 2001, n = 3 or 18; arrangement at the position of *Spiranthes romanzoffiana* plants:
KC 2002, 30; arrangement - a 10 x 12m plot
LF 2001, 10; arrangement - a rectangular frame: 2002, 30; arrangement - a 10 x 12m plot
SF 2001, n = 3; arrangement - at the position of *Spiranthes romanzoffiana* plants
At sites KA and KB data on vegetation height were gathered in spatially paired measurements 1m inside and 1m outside of the exclosures from 13 June to 6 October 2001 and on 19 September 2002. At both sites ten pairs of values were taken along one fence line where the soil was wet, with standing water at or very near the surface during wet periods; and ten pairs along another fence line where dry soil was present. Figure A5 shows the whole fence line used for the wet comparisons and the first part of the fence line used for the dry comparisons on 6 October 2001.

Further aspects of vegetation height at different parts of KA and KB in 2001 and 2002

For site KA wet and dry the difference between the inside and outside medians increases progressively throughout 2001 (Table 5). For site KB wet and dry the maximum vegetation height measurements inside the exclosure occur in August. For the wet set of values this produces the highest differences between inside and outside in August. For the dry set the outside sward was very low in October, and this resulted in the greatest difference between inside and out occurring in October.
The 19 September 2002 values broadly resemble the 6 October 2001 values, except for the KA dry set values which have some affinities with 20 September 2001 and some with 6 October 2001. Allowing for some seasonal variation, these results suggest a fair degree of similarity for early autumn values between the two years.
The wet and dry zones at sites KA and KB all had the same substrate (wind blown sand mixed with varying quantities of mildly acidic humus) and the separation between KA and KB was less than 400m. Nevertheless there were major differences in the vegetation height when comparing the same ungrazed types between the two sites (i.e. KA wet ungrazed with KB wet ungrazed, and KA dry ungrazed with KB dry ungrazed).
Height differences between apparently comparable sites (e.g. KA and KB dry ungrazed) may well reflect differences in sward biomass and provide an index of the level of competition for light amongst the sward components.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 53-68.

STUDIES ON THE CONSERVATION BIOLOGY OF IRISH LADY'S-TRESSES ORCHID, *SPIRANTHES ROMANZOFFIANA*; 2) THE ESTABLISHMENT OF 10 EXCLOSURES, DUNG COUNTS AND FURTHER STUDIES ON ASSOCIATED *JUNCUS* TAXA (SPECIES AND HYBRID RUSHES)

Richard Gulliver[1], Mavis Gulliver[2], Margaret Keirnen[3], and Christopher Sydes[4]

[1] and [2] to whom correspondence should be addressed, Carraig Mhor, Imeravale, Port Ellen, Isle of Islay, Argyll PA42 7AL, [3] Grianan, Drumclach, Isle of Colonsay, Argyll, PA61 7YR, [4] Scottish Natural Heritage, 2 Anderson Place, Edinburgh, EH6 5NP

ABSTRACT

Exclosures were established at ten sites in the Hebrides (six on Colonsay, three on Barra and one on Vatersay) at sites in two groups. Group A: where plants of *Spiranthes romanzoffiana* (a Biodiversity Action Plan species) had been recorded in previous years, but were not located in 2002; to ascertain if individuals were still present. Group B: where 1 - 2 plants were observed in 2002, and where it was suspected that the cryptic population was larger. The locations of the exclosures are referred to by code numbers to reduce the likelihood of visits by collectors of rare orchids.

100 1x1m quadrats were examined inside the exclosures for plants of *Spiranthes romanzoffiana* at three dates in 2003. On the same visits 100 1x1m quadrats were examined outside the exclosures. Vegetation and site features were recorded inside and outside. At two of the 2003 exclosure sites (pooled), seven newly recorded plants were found outside the exclosure, one newly recorded plant was found inside and five newly recorded plants within 100m of the exclosures. At the remaining eight sites no new plants were discovered.

The thirteen newly recorded plants were made up of eight vegetative plants and five flowering plants.

Within each of two of the exclosures one plant, present in 2002, occurred above ground in 2003. At a third, highly-disturbed site a plant in 2003 outside the exclosure was in the approximate position of one recorded in 2002 and 1996.

Combining new and known plants, inside and outside, four sites had *Spiranthes romanzoffiana* plants above ground in 2003.

The total number of plants (pooled over all exclosure sites, inside and outside) which were last recorded in the period 1990-1996, but which were not detected in 2003, was eighteen. The number recorded in 2001 but not in 2003 was eight; and the number recorded in 2002 and not in 2003 was two.

The two exclosure sites with the greatest number of detected plants in 2003 were in the middle of the range of values of combined counts of sheep and cattle dung, which can be used as an indicator of grazing activity.

These two exclosure sites had the lowest percentage sheep dung as a percentage of sheep and cattle dung and the lowest percentage sheep hoof holes as a percentage of sheep and cattle hoof holes in late May/early June, inside and outside pooled.

The frequency of *Juncus articulatus* and *Juncus acutiflorus x articulatus* combined in 1 x 1m quadrats varied from 6 to 100. *Juncus articulatus* frequency as a percentage of the frequency of *Juncus articulatus* or *Juncus acutiflorus x articulatus* and *Juncus articulatus* varied from 5 to 100.

Studies on the status of the small populations at and near the reference sites will continue in 2004.

Monitoring of exclosure sites in general is facilitated if the vegetation is internally uniform and is comparable between locations.

Key words or phrases: conservation, dung, exclosures, grazing, management, *Juncus articulatus*

INTRODUCTION

Spiranthes romanzoffiana (Irish lady's-tresses orchid) is a white flowered orchid (Figure B1) which blooms in July and August, (Gulliver *et al.* 2000). It can frequently be observed growing amongst the stems of *Juncus articulatus* and *Juncus acutiflorus x articulatus* (*Juncus x surrejanus*). It is currently a 'Nationally Scarce' species *sensu* Cheffings (2004), i.e. Scarce *sensu* Stewart, Pearman and Preston (1994) and a Biodiversity Action Plan Priority Species, see UK Biodiversity Action Group (1999). The number of plants recorded in large and medium sized study populations, the relationship to grazing, the height of vegetation at and near plant stations, and the results of observations on capsules are presented in Gulliver (2002), Gulliver *et al.* (2003) and Gulliver *et al.* (2004a, this volume).

The species can spend up to six years in the underground state, (Dr James Robarts *pers. comm.*). The number of plants in bloom is not a good indication of population size Gulliver *et al.* (2004a, this volume). Flowering stems are grazed by stock, and the vegetative plant is hard to detect. It is therefore very difficult to ascertain the true status of a population occurring at a site subject to grazing by stock. Gated exclosures can be used to create a summer grazing break. This generates maximum visibility of the plants that are present; and allows grazing in the autumn, winter and spring to ensure sward consumption for much of the year. Ten were established in March 2003 as part of a Scottish Natural Heritage research project at sites with small populations in two groups. Group A: where *Spiranthes romanzoffiana* plants had been recorded in previous years, but were not located in 2002. Group B: where 1 - 2 plants were observed in 2002, and where it was suspected that the cryptic population was larger. Allocation to groups A and

B was based specifically on presence in 2002 and the plant(s) being present in the exact site of the future exclosure. Sites six and nine had plants present inside the position of the subsequent exclosure in 2001 but not 2002. At site five in 2002 no plant was present within the position of the future exclosure; but one did occur in the equivalent study area outside the boundary of the future exclosure.

The aim of the research was to determine if the populations with no 2002 records were still extant; and if larger populations existed where 1 - 2 plants were detected in 2002. The break from grazing by stock during the summer months was provided to improve the possibility of plant detection. In addition, factors which might affect *Spiranthes romanzoffiana* e.g. intensity of grazing and the attributes of the site, were investigated.

METHODS

Marking the position of individual plants of *Spiranthes romanzoffiana*

Individual plants were marked by the use of an adjacent black plastic peg(s) with a 'mushroom shaped' black top. The marker peg(s) was/were 10cm from the plant. Either 1, 2 or 4 pegs were used. Referencing systems were established to permit plants to be relocated.

Any one plant may either be in the flowering (F), vegetative (V) or underground (U) phase in any one year. The underground status can only be applied after a minimum of three years study, e.g. F in year 1, U in year 2, V in year 3. Members of the Orchidaceae are maintained by mycotrophy while in the underground state, Rasmussen (1995).

At certain positions peg sinkage and loss occurred. These included locations where the ground was very soft, where it was very marshy and where there was a high level of disturbance to the substratum by stock, sometimes these features occurred in combination. The use of marker pegs commenced in 1999.

Exclosures site details

There has been a history of rare orchids being periodically dug up in the British Isles. Therefore the locations of exclosures are not identified in detail, but are referred to by code numbers.

Three of the ten exclosures were on Barra (sites one - three), one on Vatersay (site four) and six on Colonsay (sites five - ten). The characteristics of the sites and the dates of the original records of *Spiranthes romanzoffiana* from the sites of the current exclosures, and from the associated sets of 100 quadrats outside the exclosures, are given in Appendix A. Nine of the exclosures were ten metre squares, inside which 100 1 x 1m quadrats were studied in late May/early June 2003, late July/early August and late September/early October 2003. The dates of the visits are given in Appendix B. Due to topographic constraints at site five an 8 x 13m exclosure was used; data are presented for 100 of the 104 quadrats for comparative purposes. In addition the proposed positions of the exclosures were studied in 17-20 August 2002 on Barra and Vatersay and 20-24 September 2002 on Colonsay.

Each exclosure had two 2.4m gates which faced each other. These gates were closed at the end of the late May/early June visit and opened at the end of the late September/early October visit. The facing gates allow through visibility, which will help to ensure stock are not discouraged from entering and grazing during the winter months.

At each site 100 1m x 1m quadrats were studied outside the exclosures. These were located first and foremost in positions where it appeared possible that *Spiranthes romanzoffiana* might exist. The local micro topography frequently resulted in strong variation in the degree of wetness and vegetation structure over very short distances inside the exclosures. The second criterion for determining the position of the outside set of quadrats was to replicate the variation inside as far as this was possible. The micro topographic features included shallow burns, rock outcrops, and ditches, Appendix A. In addition stands of e.g. *Calluna vulgaris, and Juncus effusus* added to the variety of the structure of the vegetation. Site five provides a particularly good example of this heterogeneity. It is bisected by a very shallow burn, hence there are some burn and burnside quadrats both inside and outside, Figure B2. A track used by stock (but no longer used by humans) passes through the outside set of quadrats at right angles to the burn, resulting in much trampling and disturbance, especially adjacent to the burn. However comparatively dry substrates are present at the quadrats which are most distant from the burn, inside and out.

Thus the study plots do not resemble the more or less homogeneous stands that would be selected for the direct measurement of stand/grazing pressure interactions e.g. as utilised by Welch (1984), albeit at a larger scale, for dung studies.

The outside quadrats were either in a single block; or in two, three or four blocks, (Appendix A). At site four the outside quadrats were in a block of 80 with a contiguous extension of 21 quadrats. At site five there were 104 quadrats outside the exclosure (as well as 104 inside the exclosure). In both cases 100 quadrats from the larger number was used for comparative purposes.

Every quadrat was carefully examined for the presence of *Spiranthes romanzoffiana* leaves.

The frequency of a range of plant species including *Calluna vulgaris* (heather) was recorded on the late July/early August and/or late September/early October 2003 visits.

Assessment of grazing intensity

For each exclosure site the adjudged overall grazing intensity was assessed on the following scale, H = Heavy, L = Light, M = Moderate, V = Variable, VH = Very Heavy, VL = Very Light. The assessment integrates a) changes throughout the year (2003)

and b) the effects of localised small areas of very light or very heavy grazing.

Counts were made of the number of hoof holes per quadrat and of the number of items of sheep, and cattle dung per quadrat. Presence/absence of rabbit dung was noted.

Vegetation height (Gulliver *et al.* 2004a, this volume) was measured by first taking 10 height measurements within the 1 x 1m quadrat and then selecting the median value of this single sample (first order median).

Vegetation height was recorded in 5mm steps between 10 and 30mm and in 10mm steps thereafter. Vegetation height was measured to the point where the density of the component stems and leaves of the sward diminished appreciably. The data gathered allowed comparisons to be made within different subsections of the same site, between sites, and over time. Data from each site are summarised in the form of medians and means. As the initial values are in 10mm steps, the medians routinely vary by values of 10mm. This coarse scale may mask differences that are apparent in the mean values, which are presented to 1mm values. When interpreting these means it is important to bear in mind that the original data were gathered in 10mm steps.

Within the 1x1m quadrats more than one vegetation layer was often present. Data were gathered on the height and percentage cover, in 5% steps, of the one, two or three layers present as appropriate. The height band of each layer was broadly similar throughout, so in non grazed (or extremely lightly grazed) quadrats there would be no first layer.

Juncus articulatus* and *Juncus acutiflorus x articulatus

The relative balance of *Juncus articulatus* and *Juncus acutiflorus x articulatus* (*Juncus x surrejanus*) was recorded in terms of frequency, i.e. presence/absence per quadrat in 2002 or 2003. *Juncus acutiflorus x articulatus* was identified using the characters given in Blackstock and Roberts (1986), Stace (1997) and Rich and Jermy (1998), with particular attention being paid to the length of the ripe capsule in relation to the perianth segments and to the colour of the capsule. Sometimes the quadrat contained specimens where all the inflorescences were grazed, and taxonomic determination was not possible. Plants of *Juncus acutiflorus x articulatus* are partially fertile and produce limited quantities of viable seed, Blackstock and Roberts (1986); the taxon chiefly reproduces by far creeping rhizomes. By contrast Blackstock and Roberts (1986) state that the rhizome system in *Juncus articulatus* is subcaespitose or shortly creeping. Rhizome length will determine the openness of stands of the two taxa, indicating the desirability of recording the balance of the taxa present.

Juncus articulatus and *Juncus acutiflorus x articulatus* varied in abundance in the quadrats from occasional plants in the grass and sedge rich sward to quite dense stands, especially inside the exclosures in ditches and at the edge of the lochan (at site six).

The plant of *Juncus articulatus* or *Juncus acutiflorus x articulatus* with the height nearest the middle value in each quadrat was selected and the height, up to the point where stem and leaves thinned out markedly, measured in 20mm steps.

The Ellenberg indicator values (British version), Hill *et al.* (1999) for *Juncus articulatus* for Reaction (preference for soil pH), Nitrogen and Moisture are 6, 3, 9: the corresponding values for *J. acutiflorus* being 4, 2, 8; indicating that *J. acutiflorus* is more associated with acid, nutrient poor soils than is *Juncus articulatus.* Values for the hybrid are not provided. The values for *Spiranthes romanzoffiana* are 6, 4, 8.

Capsules

The nature of the capsules of *Spiranthes romanzoffiana* was examined at the late September/early October visits.

RESULTS

Number of plants within the 2003 exclosure sites and the associated set of 100 1x1m quadrats

A summary of the results is presented in Table 1. Plants found in 2003 are indicated in bold and their V/F status is stated. Details of the sites are given in Appendix A. The dates of the visits are provided in Appendix B.

The newly located plants were all found at two sites, five and nine, (Table 1). At the remaining eight sites no new plants were discovered. At these two sites pooled, seven newly located plants were found in the 100 1 x 1m squares outside the exclosure: one plant was found within the exclosure and five plants within 100m of the exclosures, (one of which is shown in Figure B1). The thirteen newly recorded plants were made up of eight vegetative plants and five flowering plants.

In 2002 plants had been recorded from the subsequent positions of the exclosures in three instances. Within one exclosure (at site four) one of the two 2002 plants had above ground growth in 2003; within one exclosure (at site seven) the 2002 plant did not produce above ground growth in 2003, and within one exclosure (at site eight) the single 2002 plant had above ground growth in 2003, (Table 1). Site five has a highly disturbed zone (Figure B2) adjacent to the burn, where pegs sink and sections of sward are pushed downward or sideward by cattle, located within the set of 100 quadrats outside the exclosure. The plant recorded in 2003 was in the same broad position as one in 2002 and 1996, (Table 1).

In the outside set of 100 quadrats at site seven one plant had no above ground tissue in 2003. It had flowered in 2001. Combining new and known plants, inside and outside, four sites had *Spiranthes romanzoffiana* plants with above ground growth in 2003, (Table 1).

The total number of plants (pooled over all exclosure sites; inside and outside) which were last recorded in the period 1990-1996, but which were not detected in 2003, was eighteen. The number recorded in 2001 but not in 2003 was eight; and the number recorded in 2002 and not in 2003 was two.

Vegetation height in late July/early August at sites with *Spiranthes romanzoffiana* in 2003

To facilitate comparisons between sites the height of a single general level of vegetation was measured at sites in late July/early August 2003, (excluding the zone created by the *Juncus* spp.). *Spiranthes romanzoffiana* plants occurred at sites five, eight and nine (pooled) at low e.g. 30mm and at relatively tall e.g. 130mm, vegetation heights, (Table 2). The mean values for the entire set of quadrats (n=100) were always very highly significantly greater inside than outside the exclosures.

The great variability of height values at sites five and nine, caused by the range of micro topographic features and the variety of vegetation types, has had the consequence that the coefficient of variation was high at these two sites; in three cases it exceeds 40, (Table 2).

Whereas the outside sets of quadrats were laid out over terrain that was approximately equivalent to the inside set, it is possible that an element of the inside/outside difference is due to physical and/or vegetational differences as well as an absence of grazing. The objective in selecting the positions of the outside quadrats was to maximise the possibility of locating *Spiranthes romanzoffiana* plants.

At site four one plant with above ground growth occurred inside the exclosure. It was on a very small mound in the slow flowing burn; first vegetation height of quadrat 80mm, second vegetation height 110mm. There was no dung in the hundred quadrats outside the exclosure at site four in early June and none in early August 2003, indicating minimal grazing at this site.

Dung and Hoof holes

Dung values at sites one to ten in late May/early June - i.e. immediately before the exclosure gates were closed

Table 3 shows the dung counts (sheep and cattle combined) totalled over all 100 1 x 1m quadrats inside and outside the exclosures in late May/early June 2003. The mean of the two sets of values and the rank are also shown. The gates were closed at the end of the visit to each site, hence these values are linked to the same stock densities in the relevant area as a whole.

At site eight the upper layers of the substrate were fluid and dung deposited was quickly amalgamated with the mixture of water, peaty humus and mineral material. Hence no reliable values were obtained for site eight. As a result the ranks run from 0 to 9. The ranking largely accords with general observation, site ten (rank 2 in Table 3) appeared to be the most heavily grazed overall and site four (rank 9 in Table 3) the most lightly grazed. The high count of dung at site six (rank 1 in Table 3) may be partly influenced by stock coming to the edge of the lochan to drink and/or graze the emergent vegetation.

At sites one, three, six, seven and nine the dung counts were considerably higher outside the exclosure even though the gates were open, (Table 3). For sites three, six, seven and nine the first vegetation height measurements indicated more grazing activity outside. The mean height of the first level outside and inside being; 33 and 39mm, 41 and 56mm, 37 and 43mm and 42 and 61mm respectively. (Means are quoted to 1mm: the data were gathered in 10mm steps: n ranges from 44 to 100 - not all quadrats had a first vegetation layer). At site ten the dung count was lower outside the exclosure; the first vegetation height measurements, 36 and 29mm respectively, indicated the same trend. At site five the dung count was 36 outside and 42 inside the exclosure; the height measurements here are fairly similar to each other at 34 and 37mm respectively. Greater animal activity will result in higher dung counts and lower vegetational heights.

Local features may exert an influence on the difference between the inside and outside counts in Table 3. The outside part of site three was bisected by parallel sheep paths. At site one the high outside values occurred near to the fence. Although this had only been present for circa two months, it may have been favoured as a rubbing area, such a utilisation was very conspicuous at site six, later in the year. To accommodate localised high concentrations of dung, it would be possible to exclude the top quartile of the values when comparing sites.

The two sites at which new plants were detected, sites five and nine, are midway in the range of values, both being rank 4.5, (Table 3). As well as being an indicator of grazing activity, dung counts may also show the extent of one of the sources of humus. It is conceivable that the supply of organic carbon reserves from the fungal associate of *Spiranthes romanzoffiana* plants is greater at sites with medium to high levels of dung input. Rasmussen (1995, p.98) states ‘Little is known about the distribution of orchid endophytes in nature, but it is assumed that they are widespread saprophytes, and some are possibly parasites or form other mycorrhizal associations as well.’ Further information on the biology of the fungi associated with *Spiranthes romanzoffiana*, both in the free living and mycorrhizal states, would be desirable.

Frequencies per 100 quadrats were calculated. The ranks of the means of the inside and outside frequency values were exactly the same as the ranks of the total counts. As there is more scope for differences to be expressed using counts compared with frequency values (which in this case can only have one of 100 values; or 200 when inside and outside values are pooled), counts have been used in this account.

Hoof hole counts

Conditions within the exclosures and the set of 100 1x1m quadrats varied from dry, peaty soils supporting *Calluna vulgaris* to wet, marshy zones; edges of small lochans; ditches; and small burns. A comparison of the hoof hole counts and dung counts showed that at one extreme there was firm ground which would not register hoof holes whilst dung counts were possible; and the other there were moderately wet zones where dung persisted but hoof marks were absent and marks made in wet substrate would soon cease to exist (as the material resumed its original shape). At site eight the substrate was so fluid that dung was frequently amalgamated into it. Over all sites hoof hole counts per $100m^2$ could not be used for assessing the intensity of grazing, but they were used to examine the balance of types of stock present.

Balance of sheep and cattle present as indicated by dung and hoof holes

The percentage dung due to sheep was similar for sites six (rank 4) and ten (rank 5); (Table 4). In addition the percentage hoof holes due to sheep was similar for sites six (rank 5), and ten (rank 4). Overall the rankings for percentage sheep in the two measures in Table 4 show good agreement but the effect of the three values from the Barra sites, all of 100%, should be noted.

The two sites (five and nine) with the highest count of *Spiranthes romanzoffiana* plants had the greatest percentage of dung and hoof holes being due to cattle and the lowest percentage being due to sheep dung. Hence there is a suggestion that the type of grazing animal may be an important site factor.

Lang (1989) reports the observation made by J. Raven that the greatest number of flowering spikes appear in areas where cattle have been fed in the previous winter, implying that disturbance of the soil may be beneficial to the species.

Seasonal changes in dung counts

Table 5 shows the total counts for the two sites at which new plants were detected, sites five and nine, in late May/early June (M/J), late July/early August (J/A) and late September/early October (S/O) 2003. Inside the exclosures no new dung is being added after the late May/early June count and values decline as the humus decays or is washed into the ground.

At site five the values decline progressively outside the exclosures, though to a somewhat lesser degree compared with inside. This suggests that the grazing pressure has been strong during the late winter and spring; and decreases in the summer, possibly as a result of stock moving to alternative grazing areas in the summer.

At site nine outside there is no change in the component of the dung value due to cattle from late May/early June to July/early August, but a small increase in value for sheep dung. Overall dung inputs and breakdown seem to be approximately in equilibrium for this period. The value falls in late September/early October, as at site five.

Castle and MacDaid (1972) found that dung pats produced by dairy cows on two replicate plots of a low N application and two of a high N application disappeared in 114 days, there was no significant difference between the treatments. However dung 'disintegrated' (= disappeared) in 133, 131, 109 and 79 days (overall mean 113) when deposited in mid May, late May, June and July respectively, the differences being highly significant. They do not attribute a cause to the observed results. The average area of the dung pats was found to be $580cm^2$: a voiding rate of 12.5 per day is provided in their discussion, but not in the results. Welch (1985) gives an average area of $611cm^2$ and Marsh and Campling (1970) give a voiding rate of 12.0 per day.

It is possible that there is a higher rate of decay of the organic matter in the summer when temperatures are somewhat higher. On the other hand higher winter rainfall levels may be important for carrying elements of the dung pat or dung pellet into the substrate. Climatological data for the period 1951 to 1980 for Colonsay is provided by Clarke and Clarke (1991).

Juncus articulatus* and *Juncus acutiflorus x articulatus

Abundance and frequency of the taxa

Juncus articulatus and *Juncus acutiflorus x articulatus* pooled varied in frequency from six at site two (inside) to 100 at sites seven, eight and ten (inside and outside), (Table 6). Site ten had a very high adjudged grazing level and the second highest value for dung counts, (Table 6).

Juncus articulatus was the only taxon in the Barra and Vatersay plots, but *Juncus acutiflorus x articulatus* did occur near to the outside quadrats at site four. Quadrats containing *Juncus articulatus* as a percentage of quadrats containing *Juncus articulatus* or *Juncus acutiflorus x articulatus* and *Juncus articulatus* in plots five to ten in late September 2002 (before the erection of the exclosures) varied from 5% to 100% (Table 6). Both taxa were present at all these six plots.

All the plots on Barra and the Vatersay plot were in positions exposed to strong winds from the sea. The two plots on Colonsay with the highest percentage of *Juncus articulatus* were the two nearest to the shoreline; they also appeared to be the most exposed of the six.

Height in late July/early August at sites with Spiranthes romanzoffiana in 2003

At the quadrats containing *Spiranthes romanzoffiana* at sites five, eight and nine (pooled) the height of *Juncus articulatus* and *Juncus acutiflorus* x *articulatus* (measured in 20mm steps to where stems and leaves thinned out markedly) ranged between 100 and 200mm, mean 156mm, n = 10. The mean heights for all quadrats inside at sites five, eight and nine were 176, 205 and 264mm, (n = 95, 100 and 97 respectively, see Table 6). The

height outside, for plants which had no obvious signs of having been grazed by stock, were 168, 149 and 222, n = 98, 100, 94 respectively.

Juncus articulatus was not present at the quadrat position of *Spiranthes romanzoffiana* at site four; the overall mean height inside was 202mm, n = 13 (August 2003).

Grazing

Grazing by rabbits was observed at the distal ends of *Juncus articulatus* and *Juncus acutiflorus x articulatus* stems in some of the exclosures in late July on Colonsay, and grazing by slugs at other exclosures. Sometimes both types of grazing occurred.

At heavily grazed sites *Juncus articulatus* and *Juncus acutiflorus x articulatus* can have grazed stems of approximately the same height as the rest of the grazed vegetation. At parts of very lightly grazed sites they may be ungrazed. Frequently a range of heights of both grazed and ungrazed plants was present in each quadrat. The two taxa (combined) might be used for an assessment of the intensity of recent grazing, utilising the lowest grazed stem height present in each quadrat. Observation indicates a rapid regrowth of stems following grazing, assuming no repeat grazing.

Jumping plant louse* Livia juncorum *galls

The jumping plant louse *Livia juncorum* modifies the inflorescences of *Juncus* species to form a tassel gall (Redfern and Shirley, 2002). This gall can occur at ground level as well as higher up the stem. At plots one, two and three the frequency was three, zero and nine respectively in August 2002. No data were collected at plot four. On Colonsay in September 2002 site nine had two quadrats with the gall, all other sites had no quadrats with the gall, though the gall is not uncommon on the island. The Colonsay sites were generally more heavily grazed than the Barra and Vatersay sites.

Floristic indications of variation between sites

The frequency of *Juncus effusus*, *Calluna vulgaris* and of *Sphagnum* species (pooled) is shown in Table 7. *Juncus effusus* is rank position 1 and 2 (mean of outside and inside) at sites three and ten. It is considerably less frequent at the other sites. *Calluna vulgaris* is most frequent at site nine followed by sites four and five, it has frequency values over 40% at all three of these sites. It shows a positive association with *Erica tetralix*, the Spearman rank correlation coefficient is 0.87. Sites one to three on Barra, site four on Vatersay and site nine on Colonsay have mean frequencies of 60% or above for *Sphagnum* species. Sites six and seven, on wind blown sand, have low or zero frequencies of *Calluna vulgaris* and *Sphagnum* spp. The first and second rank positions for these three study species, shown bold in Table 7, occur at six different sites: this is one indication of the variability between sites.

Capsules

All the examined capsules of *Spiranthes romanzoffiana* were shrivelled. None had expanded. Full capsule expansion and natural drying of the capsule wall was observed in *Spiranthes spiralis* in England, in October 2002, Gulliver *et al.* (2004a, this volume), but has not been known to occur in *Spiranthes romanzoffiana* in Scotland.

DISCUSSION

Reproduction and distribution of plants

The non-production of expanded capsules on any of the plants at the reference sites Gulliver *et al.* (2004a, this volume), and also at the exclosure sites, emphasises the need for more investigation on the presence and extent of sexual and vegetative reproduction in the species.

The presence of the five plants (at two stations pooled, sites five and nine) within 100m of the exclosures suggests that at some sites the species may be very thinly distributed.

Detection of plants

In the set of quadrats inside or outside the exclosures 73% of plants (both newly located and previously known) were vegetative. (The plants within 100m of the exclosures have not been included in this data set as they were only located because either they were in bloom or were immediately adjacent to plants in bloom). These findings emphasise the need for careful examination of the sward in order to assess the presence of *Spiranthes romanzoffiana* plants. A detailed search strategy of this kind is implemented at the exclosure sites.

There is a marked contrast between the number of plants detected in the unfenced set of quadrats (n = 8, seven newly located plants) and in the exclosures (n = 3, one newly located plant). The exclosures and therefore the inside quadrats were located around the position of previously recorded plants. The outside quadrats were adjacent, but positive efforts were made to select positions for the one to four blocks of quadrats where it was felt likely that *Spiranthes romanzoffiana* plants might occur. Surveys in 2004 will help to establish whether this difference in spatial distribution is genuine, i.e. whether or not there are approximately equal numbers within and outwith the exclosures.

Juncus articulatus* and *Juncus acutiflorus x articulatus

Juncus articulatus and *Juncus acutiflorus x articulatus* can tolerate heavy grazing e.g. at sites six and ten, as can *Spiranthes romanzoffiana* (Gulliver *et al.* 2003, Gulliver *et al.* 2004a, this volume). The evidence from the exclosures and from the reference sites (Gulliver *et al.* 2004a, this volume) indicates that at the present grazing regimes, both species appear to be co-existing, but long term studies are needed to verify this interpretation of the situation. The reduction of the biomass of the two *Juncus* taxa due to grazing may result in lower levels of competition with adjacent species for e.g. light and nutrients. In addition

grazing of *Juncus articulatus* tissue may limit the development of dense tufts, groups of which may form a barrier for the emergence of underground plant parts of other species.

Hoof hole counts and dung deposition

The ranking of combined sheep and dung counts shows a positive relationship with adjudged grazing intensities. Dung data are more rapid to gather than measurements of vegetation height, especially where more than one vegetation layer exists, each layer itself commonly requiring a cover estimate as it frequently does not occupy the full area of the quadrat. The results indicate that dung counts appear to be informative as a measure of grazing intensity. However local features such as drinking areas, comparatively sheltered areas, fence posts and fence lines (and the presence of barbed wire), and sheep paths may provide high counts. For four of the sites, variations which existed between values from the inside of the exclosure (before the gates were closed) and values from the outside, were reflected in differences in vegetation height of the first vegetation layer.

The percentage of hoof holes that were due to sheep was strongly linked to the percentage dung produced by sheep. For general studies of grazing activity at the sites which had a good registration of hoof holes of sheep and cattle, it may well be possible, after conducting pilot studies, to generate a regression line of dung counts on hoof hole counts. This would then allow the impact of either of the two factors on the sward to be estimated from one set of values.

Impact of grazing animals

Four of the ways in which the presence of grazing animals may affect *Spiranthes romanzoffiana* positively are a) suppression of potental competitors, b) dung deposition adding to the stock of humus in the soil and favouring relatively high rates of organic matter breakdown generally; which may result in enhanced heterotrophic activity by the fungal associate of *Spiranthes romanzoffiana* plants, c) trampling being associated with root breakage and possible movement of root fragments by the hooves of cattle and sheep, d) the creation of open areas by stock movement and trampling, these having high levels of light availability. Grazing will have a negative effect by removing leaves, stems and inflorescences. Trampling will damage tissue of *Spiranthes romanzoffiana* and dung deposition will blanket out the light for a period.

Site monitoring, including dung counts, and studies on the interaction between a variety of biotic and abiotic factors will continue in 2004. This monitoring will generate further information on the conservation biology of *Spiranthes romanzoffiana*.

ACKNOWLEDGEMENTS

a) Groups and organisations: the owners, farmers and crofters of the sites; Scottish Natural Heritage; the Botanical Research Fund; the Professor Blodwen Lloyd Binns Bequest Fund of the Glasgow Natural History Society: Scottish Executive Rural Affairs Department.

b) Individuals, Dr Neil Cowie; Mr Alan Forrest; Ms Verena Forster, Dr Mark Gardener; Ms Emma Grant; Mr Jonathan Grant, Mr Nigel Grant; Dr Mark Hill; Dr Frank Horsman; Dr Marilyn Light; Mr Alex Lockton; Mr Darach Lupton, Ms Rae McKenzie, Mr Philip Oswald; Dr James Robarts; Professor Clive Stace; Dr Robin Sutton.

REFERENCES

Blackstock, T.H. and Roberts, R.H. (1986) Observations on the morphology and fertility of *Juncus* x *surrejanus* Druce ex Stace & Labinon in north-western Wales. *Watsonia* 16, 55-63.

Castle M.E. and MacDaid, E. (1972) The decomposition of cattle dung and its affect on pasture. *Journal of the British Grassland Society* 27, 133-137.

Clarke, P.M. and Clarke, J. (1991) *The flowering plants of Colonsay and Oransay*. Printed by the Harlequin Press, Oban, Argyll: privately published by the authors.

Cheffings, C. (2004) New plant status lists for Great Britain. *BSBI News - the newsletter of the Botanical Society of the British Isles* 95, 36-43.

Gulliver R.L. (2002). *Dr Richard Gulliver action plan research into the ecology of* Spiranthes romanzoffiana *in Scotland*. viii & 124pp. Unpublished report to Scottish Natural Heritage.

Gulliver, R., Gulliver, M., Keirnen, M., and Sydes, C. (2004a). Studies on the conservation biology of Irish lady's-tresses orchid, *Spiranthes romanzoffiana* 1) Population sizes, grazing, vegetation height and capsule status at reference sites. *The Glasgow Naturalist*. Current volume.

Gulliver, R.L., Gulliver, M. and Sydes, C. (2003) The relationship of a Biodiversity Action Plan (BAP) orchid, *Spiranthes romanzoffiana*, to grazing in the West of Scotland. Aspects of Applied Biology 70: *Crop quality: its role in sustainable livestock production*. Published by the Association of Applied Biologists c/o Horticulture Research International, Wellesbourne, Warwick CV35 9EF, UK. (This conference had a section on biodiversity) pp. 143-150.

Gulliver, R., Keirnen, M., Gulliver, M. and Sydes, C. (2000) Observations on Irish lady's-tresses orchid (*Spiranthes romanzoffiana*) on Colonsay (vc102). *The Glasgow Naturalist* 23 (5), 9-12.

Hill, M.O., Mountford, J.O., Roy, D.B., and Bunce, R.G.H. (1999) *Ellenberg's Indicator values for British Plants. ECOFACT Volume 2 Technical Annex*. Institute for Terrestrial Ecology, Huntingdon, Cambridgeshire.

Lang, D. (1989) *A guide to the wild orchids of Great Britain and Ireland*. Oxford Universiy Press, Oxford.

Marsh, R and Campling, R.C. (1970) Fouling of pastures by dung. *Herbage Abstracts* 40, 123-130.

Redfern, M. and Shirley P. (2002) British plant galls; identification of galls on plants and fungi. *Field Studies* 10, 207-531.

Rich, T.C.G. and Jermy, A.C. (1998) *Plant Crib 1998*. Botanical Society of the British Isles, London.

Rasmussen, H.N. 1995. *Terrestrial Orchids from Seed to Mycotrophic Plant*. Cambridge University Press, Cambridge.

Stace, C.A. (1997) *New Flora of British Isles, Second Edition*. Cambridge University Press, Cambridge.

Stewart, A., Pearman, D.A. and Preston, C.D. (eds.) (1994) *Scarce plants in Britain*. Joint Nature Conservation Committee, London.

UK Biodiversity Action Group (1999) *Tranche 2 Action Plans Volume 3. Plants and fungi*. English Nature, Peterborough.

Welch, D. (1984) Studies in the grazing of heather moorland in north-east Scotland I. Site descriptions and patterns of utilization. *Journal of Applied Ecology* 21, 179-195.

Welch, D. (1985) Studies in the grazing of heather moorland in north-east Scotland IV. Seed dispersal and plant establishment in dung. *Journal of Applied Ecology* 22, 461-472.

Table 1. Number of flowering plants (F) or vegetative plants (V) of *Spiranthes romanzoffiana* detected in 2003, shown bold, and details from previous years at 10 locations with exclosures.

To economise on space, categories which currently hold no records are not included in the table.

	Exclosure					**Unfenced set of 100 1x1m quadrats outside the exclosure**			**Within 100m of exclosure**
Site and Group (A or B) see Introduction	Non appear-ance of 1990-1996 plants. Marker pegs not used	Non appear-ance of 2001 plants. Marker pegs used, some lost through sinkage	Non appear-ance of 2002 plants. Marker pegs used, none lost through sinkage	***Presence of 2002 plants above ground***	**Newly located plants**	Non appear-ance of 2001 plants	***Presence of 2002 plants above ground***	**Newly located plants**	**Newly located plants**
Barra									
1(A)	4	-	-	-	-	-	-	-	-
2(A)	4	-	-	-	-	-	-	-	-
3(A)	7	-	-	-	-	-	-	-	-
Vatersay									
4(B)	-	-	1	*1V*	-	-	-	-	-
Colonsay									
5(A[a])	1	-	-	-	**1F**	-	*1F*[b]	**1F,4V**	**2F,2V**
6(A)	1	6	-	-	-	-	-	-	-
7(B)	-	-	1[c]	-	-	1	-	-	-
8(B)	-	-	-	*1V*[c]	-	-	-	-	-
9(A)	-	1	-	-	-	-	-	**2V**	**1F**
10(A)	1	-	-	-	-	-	-	-	-
Total	18	7	2	*2*	**1**	1	*1*	**7**	**5**

Notes

[a] Group A for the area inside the exclosure. One 2002 plant (see note b) occurred outside the exclosure.

[b] This may the same plant as one recorded in 2002 and 1996. However there has been a sinkage of pegs from 2002 to 2003 (pegs were not used in 1996, a sketch plan was produced).

[c] Present in 2002, first found 2001, see Appendix A.

Table 2. Heights of the single vegetation level e.g. excluding *Juncus* spp., at sites five, eight and nine, measured in July 2003 outside and inside the exclosures[a], plus values for individual quadrats containing *Spiranthes romanzoffiana* plants.

	Site five		Site eight		Site nine	
	Outside	Inside	Outside	Inside	Outside	Inside
Mean height	54	83	65	123	72	101
Coeff. of Var. [b]	**43**	26	17	17	**48**	**45**
Median height	50	80	60	120	60	90
Range	30-120	30-140	40-100	70-180	30-220	50-300
No. of values	100	100	100	100	100	100
Value of z (n=100)	9.40		24.10		5.11	
Significance	VHS		VHS		VHS	
Single vegetation level heights at individual quadrats containing *Spiranthes romanzoffiana* plants						
	30, 40, 50 50, 50, 50	90		130	30, 50	

Notes

VHS Very Highly Significant

[a] In early August 2003 one plant occurred at site four inside the exclosure, on a very small mound in the slow flowing burn; lower vegetation height of quadrat 80mm, upper vegetation height 110mm. There was no dung in the hundred quadrats outside the exclosure.

[b] Coefficient of variation, values of 40 and above are shown bold.

Table 3. Total count in 100 1 x 1 m quadrats of sheep and/or cattle dung at exclosure sites 1 - 10 in late May/early June 2003.

Site Number	1	2	3	4	5	6	7	8	9	10
Outside exclosure (O)	29	14	68[a]	0	36	90[ab]	27[a]	ND	41[a]	64[c]
Inside exclosure (I)	8	15	24	0	42	67	15	ND	17	73
Mean Outside + Inside	18.5	14.5	46	0	39	78.5	21		29	68.5
Rank	7	8	3	9	4	1	6	ND	5	2
Adjudged intensity of grazing and rank	L 7.5	L 7.5	M(V) 4.5	VL 9	M 4.5	H (V) 2	M 4.5	M not inc.[d]	M 4.5	VH(V) 1

Notes

H = Heavy, I = Inside exclosure, L = Light, M = Moderate,

ND Not Determinable: dung sinks rapidly into the fluid upper layers of the substrate

O = Inside exclosure, V = Variable, VH = Very Heavy, VL = Very Light

[a] The vegetation height data also indicated heavier grazing outside the exclosure cf. inside for 3, 6, 7 and 9.

[b] Dung counts were not determinable at 5 quadrats due to 100% standing water.

[c] The vegetation height data indicated lighter grazing outside the exclosure cf. inside at 10.

[d] Not included in the ranking to allow comparability with dung counts.

Table 4. Percentage of total count of dung and hoof holes that was due to sheep at exclosure sites 1 - 10.

Data gathered late May/early June 2003 immediately before gate closure, inside and outside values pooled

Site Number	1	2	3	4	5	6	7	8	9	10
Dung count % sheep	100	100	100	No dung[a]	13	95	86	ND[b]	41	93
Rank 1-8	2	2	2		8	4	6		7	5
Hoof hole count % sheep	100	100	100	No hoof holes [c]	1	56	43	ND[b]	19	57
Rank 1-8	2	2	2		8	5	6		7	4

Notes

[a] No dung present.

[b] ND Not Determinable: dung sinks rapidly into the fluid upper layers of the substrate.

[c] No hoof holes present.

Table 5. Total count in 100 1 x 1 m quadrats of sheep and/or cattle dung at exclosure sites five & nine in late May/early June (M/J), late July/early August (J/A) and late September/early October (S/O) 2003.

Site Number	5 M/J	5 J/A	5 S/O	5 M/J - S/O	9 M/J	9 J/A	9 S/O	9 M/J - S/O
Outside exclosure	42	39	21	21	17	20	10	7
Inside exclosure	36	13	8	28	41	8	1	40

Table 6. *Juncus articulatus* and *Juncus acutiflorus* x *articulatus* at sites 1 – 10.

Site Number	1	2	3	4	5	6	7	8	9	10
Frequency of both *Juncus articulatus* and *Juncus acutiflorus* x *articulatus*, pooled, in 2003										
	late Sep./early Oct. 2003 (for comparison with taxonomic determinations)				late Jul./early Aug. 2003[a] (relates to height measurements in text)					
Outside	20	7	46	17	98	75	100	100	94	100
Inside	35	6	85	21	95	99	100	100	97	100
Juncus articulatus frequency as a percentage of the frequency of *Juncus articulatus* or J. *acutiflorus* x *articulatus* and *Juncus articulatus* for quadrats with one or both taxa[b]										
	late Sep./early Oct. 2003 (28 Sep. - 6 Oct.) (plants ungrazed)				late Sep. (20-24) 2002 (plants grazed: records from 100 1x1m quadrats before exclosure erected)					
Inside	100[c]	100[c]	100[c]	100[cd]	92	100	65	43	10	5

Notes

[a] Full frequency count and height measurements were in late July/early Aug 2003 at sites 5-10. In Sep./early Oct. 2003 a sample was taken.

[b] Plants not determinable due to grazing of floral parts excluded throughout from this data set.

[c] All outside i.e. grazed plants (recorded in 2003) were *Juncus articulatus* at sites 1-4.

[d] *Juncus acutiflorus* x *articulatus* occurs nearby.

Table 7. Frequency of *Juncus effusus*, *Calluna vulgaris* and *Sphagnum* species in 2003, to indicate aspects of the wetness and variability of the sites (see also Appendix A).
Rank positions 1 and 2 are shown bold

Site Number	1	2	3	4	5	6	7	8	9	10
Juncus effusus Late September/early October										
Outside	1	0	26	9	34	5	7	0	12	47
Inside	3	7	64	14	6	9	0	15	8	34
Mean Outside + Inside	2	3.5	45	11.5	20	7	3.5	7.5	10	40.5
Rank	10	8.5	**1**	4	3	7	8.5	6	5	**2**
Calluna vulgaris [a] Late September/early October										
Outside	8	18	3	61	26	3	0	2	70	0
Inside	6	17	1	79	61	0	0	0	73	0
Mean Outside + Inside	7	17.5	2	70	43.5	1.5	0	1	71.5	0
Rank	5	4	6	**2**	3	7	9.5	8	**1**	9.5
***Sphagnum* spp.** Late July/early August										
Outside	96	100	59	93	7	0	0	13	75	4
Inside	100	97	62	92	31	0	0	18	89	0
Mean Outside + Inside	98	98.5	60.5	92.5	19	0	0	15.5	82	2
Rank	**2**	**1**	5	3	6	9.5	9.5	7	4	8

Notes

Erica cinerea had a frequency of 2 Outside at site five; and 2 Outside, 1 Inside at site nine.

The Spearman rank correlation coefficient for the association of *Calluna vulgaris* and *Erica tetralix* is 0.87, using mean of Outside and Inside values. The association is Very Highly Significant.

Appendix A

Appendix A Site characteristics of exclosure plots plus original record of plants in the general locations of the 2003 exclosures in two categories; I) inside = within the exclosures when subsequently erected O) outside = in an unfenced set of 100 1x1m quadrats adjacent to or around the exclosure.

Code	Grazing [a]		Study site attributes, I and O unless indicated					Date	No. of plants	
Site & Group (A or B) see Introduction	Grazing vertebrate. Most abundant first	Adjudged overall intensity of grazing[a]	Slope: flat (F), gentle slope (GS) sloping (S), very gentle slope (VGS)	Presence of burn (BU), ditch (DI), lochan shore (LS), marshy subsection (MS) or flat wet area (FW).	Light (D) or heavy (DD) disturbance of margins of BU, DI or LS: or of marshy or flat wet areas	Presence (P) of dry zones, other than the margins of protruding Rocks	Number of blocks of quadrats outside the exclosure	Date of original record	Inside subsequent 2003 exclosure plot	In subsequent unfenced set of 100 1x1m quadrats
Barra										
1(A)	S	L	VGS				4	1990	4	
2(A)	S	L	F	FW			3	1990	4	
3(A)	S	M (V)	S	DI	D	P	1	1990	7	
Vatersay										
4(B)	S,C[b]	VL	F	BU	D		1	15/08/02	2	
Colonsay										
5(A)	S,C	M	F	BU	DD	P	1	18/08/96	1	1
6(A)	S,C	H(V)	F	LS	DD	P	2	27/7/95[c]	1/6[c]	
7(B)	S,C	M	GS	MS - O	D		2	30/07/01	1	1
8(B)	S,C	M	F	FW	DD	P[d]	1	14/08/01	1	
9(A)	S,C	M	F	DI	DD		3	14/08/01	1	
10(A)	S,C	VH(V)	S			P	1	17/08/96	1	

Notes

C = Cattle, F = Flat, G = Geese, GS = Gentle Slope, H = Heavy, L = Light, MS = Moderate slope,
R = Rabbit, S = Sheep, V = Variable, VGS = Very gentle slope, VH = Very Heavy, VL = Very Light

[a] And other activities related to stock presence e.g. trampling.
[b] Grazed by cattle in the winter months.
[c] 27/7/95 for I plant: 16/5-14/08/01 for 6 plants.
[d] As a low bank c.30cm wide on one side of both I and O areas.

Appendix B

Appendix B Dates of visits to exclosure sites in 2002 & 2003

Site	2002	2003	2003	2003
Barra				
1	20 August	1-2&4 June	3 August	28-29 September
2	21 August	2-3 June	4 August	29-30 September
3	19 August	4 June	5-6 August	30 September to 2 October
Vatersay				
4	17 August	5 June	7-8 August	3-6 October
Colonsay				
5	23 September	21-22 May	26-31 July	20-21 September
6	20 September	26 May	28-29 July	19 September
7	24 September	25 May	29-30 July	18 September
8	23-24 September	23 May	25 July	17-18 September
9	22-24 September	28-30 May	23&31 July	24 September
10	22 September	24 May	25-26 July	21-22 September

LEGENDS TO COLOUR FIGURES FOR PAPER 1 AND PAPER 2 BY
Richard Gulliver, Mavis Gulliver, Margaret Keirnen, and Christopher Sydes.

Figure A1.
Irish lady's-tresses orchid (*Spiranthes romanzoffiana*) with 13 fully open flowers on 11/8/99 at site KA. The stems and leaves of *Juncus acutiflorus* x *articulatus* form an upper layer at 300mm. The first vegetation layer, around the base of the plant, is 100mm; with a zone of stoloniferous, dicotyledonous plants at 20mm.

Figure B1.
A newly discovered plant of *Spiranthes romanzoffiana* on 28/7/03 within 100m of the exclosure at site five. The two bottom stem leaves and one surviving basal leaf have been truncated by vertebrate grazing. Twelve of the flowers were open, seven unopen. The plant was surrounded by *Juncus acutiflorus x articulatus* stems, leaves and flowers (some present in the photograph but somewhat out of focus); *Juncus articulatus* occurred 80cm from the plant.

Figure A2.
Spiranthes romanzoffiana in bloom on Colonsay on 9/8/95. Careful examination of the illustration shows that the bract of the left hand flower has been truncated. In addition the two upper stem leaves appear to have been truncated and the partly withered. These features suggest that grazing has occurred at the time when the whole inflorescence was emerging from the ground. Such an event might have removed the upper flowers; these are the last to open, when the inflorescence is fully developed. This would explain the uniformity in stage of development of the six flowers that are present.

Figure A3.
Spiranthes romanzoffiana, plant A4 at site GF on Coll on 1/10/02, showing withered, unexpanded capsules. Photograph Ms. Emma Grant.

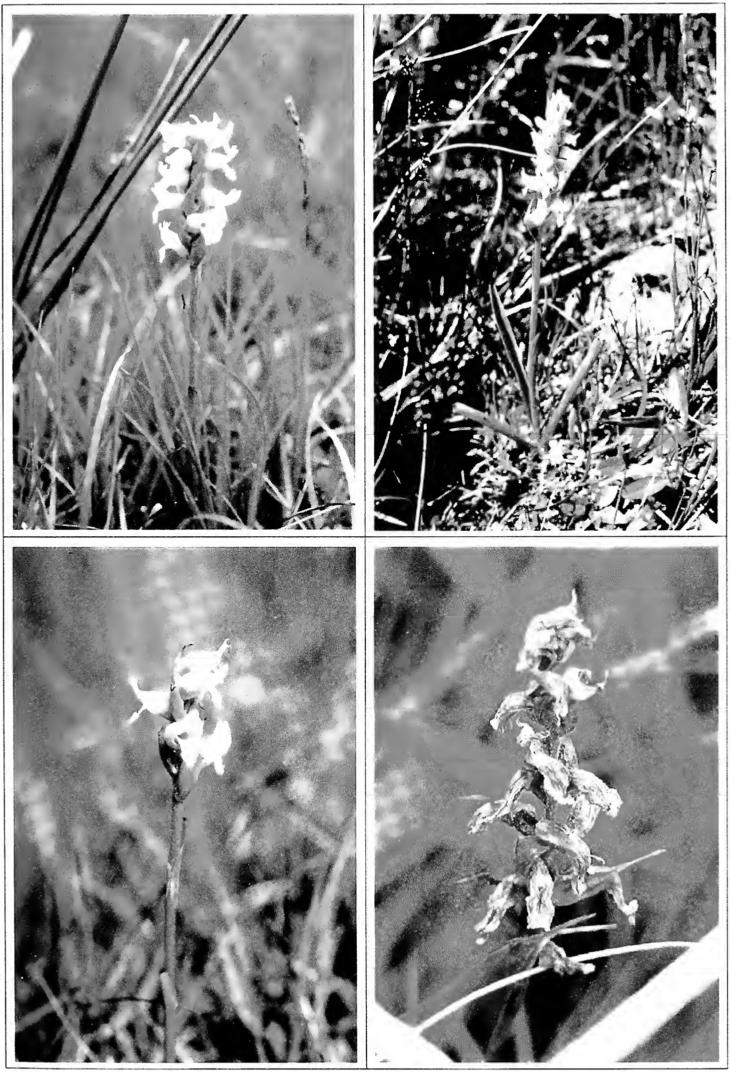
Figure A4.
Autumn lady's-tresses orchid (*Spiranthes spiralis*) in bloom on 13/08/90 on the Gower in South Wales

Figure A5.
The exclosure at site KA on 6/10/01. The fence line immediately behind the corner post divides the grazed wet sampling stations (right) from the ungrazed wet sampling stations (within the exclosure). To the left of the corner post is the first of the dry sampling stations.

Inside the exclosure *Juncus* spp. (mainly *Juncus acutiflorus* x *articulatus*) are present in the second vegetation layer (which appears more dense on the photograph than is the case on the ground). Outside the fenceline they have been grazed down.

Figure A6.
Spiranthes spiralis in Cumbria on 18/10/02. Photograph Mr David Benham. The lower capsules have become fully expanded ('inflated'), dried naturally and then developed slits which allow the seeds to be shed. This is best shown in the lowest capsule on the right hand side.

Figure B2.
Part of row A (extreme left) and of row B, outside the exclosure, at site five on 27/7/03, showing the small burn with trampled margins. The track which passes through the outside quadrats at the site is more clearly visible in the background. The tape on the right of the picture shows the outer boundary of the outside set of quadrats.



Figures A1 upper left, B1 upper right, A2 lower left, A3 lower right.




Figures A4 upper left, A5 upper right, A6 lower left, B2 lower right.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 69-70.

REDISCOVERING THE FIRTH OF FORTH BELUGA

Andrew C. Kitchener and Jerry S. Herman
Dept. of Geology and Zoology, National Museums of Scotland, Chambers Street, Edinburgh EH1 1JF
E-mail:a.kitchener@nms.ac.uk, j.herman@nms.ac.uk

The beluga, *Delphinapterus leucas* (Pallas), is an Arctic cetacean, which has been recorded rarely in Britain from sightings and strandings (Barclay & Neill, 1821; Fraser, 1934, 1974; Evans, 1991, Flower, 1880; Millais, 1906; Turner, 1912). Records of strandings from Scotland comprise two young males that were stranded in August 1793 east of Thurso in the Pentland Firth, a specimen at Auskerry, Orkney in October 1845, a specimen near Dunrobin, Sutherland in June 1879, another at Wick in 1884 and finally one near Stirling in the Firth of Forth in October 1932.

There is an earlier record of a beluga in the Firth of Forth, where an animal was frequently observed for about three months in 1815 in between Alloa and Kincardine (Barclay & Neill, 1821). It swam upstream on the incoming tide and downstream on the ebb. Many attempts were made to kill it before it succumbed eventually to the firearms and spears of salmon-fishers on 6th June 1815 at the Abbey of Cambuskenneth, Stirling while in the pursuit of salmon. The animal was purchased by Robert Bald, who sent it to Professor Jameson in Edinburgh, having saved it from going to Glasgow (!) or being "cut to mince-meat for a soap-work".

This beluga was described by Neill and dissected by Barclay (Barclay & Neill, 1821). The animal was a male and measured 13 feet 4 inches (4 metres) in a straight line. This specimen was supposedly the source of a skin that was mounted for display in the Natural History Museum of the University of Edinburgh (Evans, 1892). Unfortunately, this stuffed beluga appears to have been disposed of by the Royal Scottish Museum in the early 1950s.

However, close examination of Barclay & Neill (1821) reveals that it was highly unlikely that this specimen's skin could have been prepared for display. Neill described the soft parts as "quickly passing into a state of putrefactive fermentation" and Barclay regretted that his dissection was very incomplete because of the "putrid state of the body, and the shortness of time which I had to examine it". Plate XVIII (Barclay & Neill, 1821) shows that extensive areas of skin had apparently been cut away to allow Lizars to sketch the viscera *in situ*, although this could have been artistic licence. Barclay also described putting pieces of the skin into spirit, which hardly seems consistent with saving its skin for a museum display.

Curiously, no mounted specimen of beluga is recorded in the registers of the National Museums of Scotland (NMS) and its predecessors. Therefore, it is unclear from where the stuffed beluga originated. It is possible that Evans (1892) inadvertently linked the story of the Firth of Forth beluga with the stuffed specimen in the Edinburgh Museum of Science and Art (now NMS).

All that appears to have been preserved from the Firth of Forth beluga was the skull, vertebral column and ribs of the skeleton (Barclay and Neill, 1821, p. 388). However, the whereabouts of this skeleton is unknown. It could have been in the collection of the Royal College of Surgeons in Edinburgh, where Barclay was based. However, much of Barclay's collection was destroyed in the 1960s and no beluga skeletons survive there today.

Today NMS's collections contain three beluga skulls (Herman, 1992). Two of these are of Arctic origin, but one (register no. NMSZ1956.36.54) lacks data and originated from the Turner Collection in the Anatomy Department of Edinburgh University (Turner, 1912; register no. C.Dpt.1.1). Turner's (1912) only comment about this skull was that it was from the Monro Collection. Herman (1992) erroneously recorded this skull as being from a female, but it is unsexed.

We compared the published measurements of the skull above (Turner, 1912) with those of the Firth of Forth beluga (Barclay & Neill, 1821). Although the skull widths matched (i.e. 11 inches [=279 mm]), the length of the Turner/Monro specimen was one inch shorter (i.e. 20 inches compared with 21inches [=508 mm compared with 533 mm]) . However, we re-measured the Turner/Monro skull and found that it was exactly the same length as the Firth of Forth specimen (Barclay & Neill, 1821). This suggested that the Turner/Monro specimen could be the lost Firth of Forth beluga.

Other evidence to support this view comes from damage caused to the skull, presumably during the dissection. For example, Barclay noted that "I once observed the front teeth in the lower jaw, but before we proceeded to the dissection, some person had secretly extracted them". The teeth are absent from the mandible of the Turner/Monro skull and the alveoli are covered in as much soot from gas lamps as the rest of the mandible, suggesting that they have always been missing since the specimen was prepared. The cranium has been crudely split in two, with saw marks still evident on the right hand side. Barclay did attempt to look at the brain, but found "The brain was putrid".

Taking the skull measurements, the missing teeth and damaged cranium together, it is highly suggestive that the Turner/Monro beluga skull is that of the missing Firth of Forth beluga. Other specimens from the Turner collection are known to have originated from the Royal College of Surgeons, so the transfer of the skull to the Anatomy Department is not unusual. However, a mystery remains – the location of the rest of the skeleton.

References

Barclay & Neill (1821). Account of a beluga or white whale, killed in the Frith of Forth. *Memoirs of the Wernerian Natural History Society* 3, 371-395.

Evans, W. (1892). *The mammalian fauna of Edinburgh.* M'Farlane and Erskine, Edinburgh.

Fraser, F.C. (1934). *Report on Cetacea stranded on the British coasts from 1927 to 1932.* British Museum, London.

Fraser, F.C. (1974). *Report on Cetacea stranded on the British coasts from 1948to 1966.*British Museum (Natural History), London.

Flower, W.H. (1880). Exhibition of, and remarks upon, the skull of a beluga or white whale (*Delphinapterus leucas*). *Proceedings of the Zoological Society of London* 1879, 667-669.

Herman, J.S. (1992). *Cetacean specimens in the National Museums of Scotland.* National Museums of Scotland, Edinburgh.

Millais, J.G. (1906). *The mammals of Great Britain and Ireland, vol.3.* Longman, Green & Co, London.

Turner, W. (1912). *The marine mammals of the Anatomical Museum of the University of Edinburgh.* Macmillan, London.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 71-78.

CLIMATE CHANGE AND ITS EFFECTS ON CATCHMENT HYDROLOGY OF THE RIVER SPEY, SCOTLAND, THE RIVER NECKAR, GERMANY, AND THE RIVER ALPENRHINE, SWITZERLAND

Gerrit Klemm

Department of Civil Engineering, University of Glasgow, G12 8QQ, <klemm@civil.gla.ac.uk>

ABSTRACT

Climate ehange is controlled by many different factors. These include solar radiation, atmospheric gases and volcanism. The prediction for a climate change in the near future is a temperature increase in the range of 0.5°C and 4.5°C by the year 2030, but varies for different regions. The responses of hydrological regimes to climate change are reviewed, and the role of General Circulation Models, Hydrological Models, and their coupling, are described in the context of climate change. Potential changes in sediment discharge carried by rivers is also described. The change in discharge of rivers in response to climate change is difficult to predict because the locality of different rivers has very specific characteristics.

The level of uncertainty of a prediction of the response of hydrological regimes is quite high due to difficulties in modelling climate relationships. Recently published results, based on GCMs, predict a general increase in precipitation and in some regions (e.g. mountain areas, like the Alpenrhine catchment) also a change in the seasonality of rainfall. It is also difficult to assess the changes in river discharge, because there are too many factors of the prevailing catchment to be considered for a general statement to be made. The effects of climate change on sediment transport have rarely been the topic of climate change research so far.

Three rivers are considered in detail, the River Spey in Scotland, the River Neckar in Germany, and the River Alpenrhine in Switzerland.

In the River Spey catchment, the present-day rainfall pattern shows weak seasonality with a slight tendency towards more rain in the autumn and winter period. The consequence is that floods are approximately evenly distributed throughout the year, but in the case of large basins, such as the Spey catchment, more pronounced winter-dominated flooding is to be seen. For continuous climate warming, the future prediction is that there will be an increase in runoff due to a significant increase in winter rainfall. In other words there will be more pronounced seasonality for the winter season and there may also be more concentrated periods of rain. The influence of snowmelt is almost insignificant.

In the River Neckar catchment, the present pattern of rainfall and runoff shows that there are two main seasons, winter/spring and summer/autumn. The winter precipitation is partly stored as snow but this is not as high as for the River Alpenrhine. Floods usually occur in late autumn and at the end of winter/beginning of spring. In the autumn the floods are just rain-fed, while melted snow will additionally feed the spring runoff. All in all, the winter and spring runoffs are higher than the summer and autumn ones. Increased temperature would lead to an increased runoff in winter, and a decreased runoff in spring and summer, of which the summer would be the driest season.

The River Alpenrhine catchment shows clear seasonality for rainfall and for floods. At the present all four seasons are almost independent. In winter the precipitation is stored as snow and the temperatures are so low that the runoff is minimal. In late spring the runoff caused by precipitation is additionally increased by the volume of melt-water from the snowmelt. The summer and autumn differ in the amount of precipitation and runoff. Here, the changes caused by increased temperature will be very significant. The time during which the winter precipitation is stored as snow will decrease considerably, and therefore the immediate runoff will increase drastically (Kwadijk and Rotmans, 1995). As a consequence the volume of melt-water will decrease and will not be available anymore for the spring and partly also for the summer. Additionally, the precipitation will decrease in the summer and at the beginning of autumn. Basically, this means that the River Alpenrhine would change from a snowmelt fed river to a rain-fed river.

INTRODUCTION

Throughout the Earth's history its climate has changed by cooling and warming, with other aspects of climate such as rainfall also fluctuating as a result. Global patterns of climate also change differently in different regions. The timescales of periods of global warming and cooling include decades, centuries, millennia and millions of years. Most interesting for the purposes of environmental biologists and water engineers are changes that occur on a relatively short time scale of decades or centuries. On such a short time scale, the last period of global cooling ended in the mid-1960s, which can be seen in Figure 1 (Dawson, 1992).

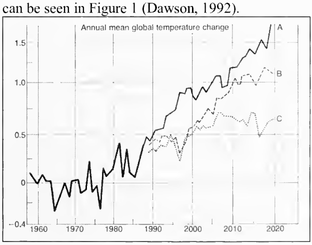


Figure 1: Trends in global temperature during the last 30 years (from Dawson, 1992)

Since then, the Earth has been in a period of global warming and the prediction is that this period will continue. However it is almost impossible to say for how long this will go on (Dawson, 1992).

In this article the author will review the factors which influence global climate, and then consider the effects of global warming on three representative rivers, one in Scotland, one in Germany, and one in Switzerland. The research presented is based on knowledge and facts as they were available in 1999.

CLIMATE CHANGE

Solar Radiation

The most fundamental factor exercising the greatest influence over the climate is the Sun. Solar radiation is not constant. It fluctuates in a cyclical manner mainly due to the Earth's orbital mechanisms. An explanation for the onset of ice ages is that they are triggered by changes in the tilt of the Earth around the Sun and to changes in the tilt of the Earth's axis, which change the distance between the Earth and the Sun and so cause a climate change (Dawson, 1992). Smaller climate changes over short periods (a few decades) are also set off by this mechanism.

Atmospheric Gases

The Earth's atmosphere is another major factor. In general terms, the response of the atmosphere to solar radiation is threefold: absorption, scattering and reflection. Changes in the concentration of atmospheric gases will induce global changes in temperature. The absorption of outgoing long-wave radiation by carbon dioxide (CO_2), methane (CH_4) and water vapour has come to be known as the "greenhouse effect" owing to the retention of heat by these gases (Dawson, 1992).

The greenhouse effect is caused by the blocking of outgoing radiation by a number of gases in the troposphere, which is the lowest layer of the atmosphere, in which weather processes take place. Principal among these are carbon dioxide and methane, both of which absorb, scatter and reflect this radiation. As a result temperatures in the troposphere, are much higher than they would otherwise be. The large increase in the amount of carbon dioxide, as the major greenhouse gas in the atmosphere, is mainly due to the burning of coal and oil and the removal of large areas of forest cover. The role of other absorbing gases (nitrous oxide, ozone, methane, and chlorofluorocarbons (CFC's)) is claimed to be already as important as that of carbon dioxide (WMO, 1986). Should the present trends be maintained, it is estimated that by about 2030 AD the combined effects on the terrestrial radiation balance of all those gaseous constituents could be nearly the same as the effect that would be induced by doubling of the pre-industrial level of atmospheric carbon dioxide (WMO, 1986).

Volcanism

Volcanic activity is another very important factor inducing climate change. Scientists have long known that major explosive volcanic eruptions often result in global cooling. Such eruptions are mostly associated with the injection of large quantities of volcanic ash into the stratosphere where the ash can persist for several years. This ash absorbs incoming solar radiation and is heated (Dawson, 1992).

Predicted Future Climate

Despite the enormous amount of information on past climates now available, the task of accurate climate prediction is still as elusive as ever (Dawson, 1992). Nevertheless, most predictions of global warming in the near future assume doubling of the carbon dioxide concentration in atmosphere. It would entail large perturbations in the present climate, notably an increase in temperature and absolute humidity within the near surface air layer (Kellogg, 1979; Watts, 1980; Berger, 1981; Clark, 1982; Manabe, 1983; Flohn and Fantechi, 1984), a decrease in net terrestrial and global solar radiation (Chou et al., 1982; Ramanathan, 1981) and modifications in the annual rainfall regime and in the nebulosity (Manabe et al., 1981; Washington and Mehl, 1983, 1984; Mitchell, 1983, 1986). Predicted increases in temperature lie between 0.5°C and 4.5°C by the year 2030 and differ for various regions (van Dam, 1999). Hence, predictions of climate change show many uncertainties and their use for secondary predictions such as the response of hydrological regimes have to be handled with care. Nevertheless, this prediction was acknowledged by the Intergovernmental Panel on Climate Change (IPCC, 1985) as the standard of the recent research in the field of climate changes.

RESPONSE OF HYDROLOGICAL REGIMES TO CLIMATE CHANGE

Changes in Rainfall and Runoff

All predictions of future climate scenarios are based on General Circulation Models, while the hydrological aspects are based on hydrological models. In order to obtain results for the response of hydrological regimes to climate change, two of these different types of model are usually coupled.

General Circulation Models (GCMs)

GCMs are used to obtain descriptions of current atmospheric processes. At present there are only a few of these models, because they require a considerable effort to design, and they can only be implemented and run on very large-capacity computers.

The areas modelled by GCMs are subdivided into grid cells with horizontal dimensions of the order of 300x300 km^2 to 1000x1000 km^2. In the vertical direction, the Earth's atmosphere is subdivided into six, ten, or more layers, each several hundred metres thick. The temporal resolution is in the order of 30 minutes to 1 hour.

The atmospheric processes modelled by GCMs are based on mathematically formulated physical laws. The various GCMs differ not only in grid sizes and the number of layers, but also in the number of processes and relevant parameter values that can be included (van Dam, 1999). The weak points of GCMs are their inability to model the physics of clouds properly, and do not take account of the presence and effects of aerosols and volcanism, which can have a great influence on climate changes. Therefore the results obtained from various models are often quite diverse. Another reason for the differing results is that the important elements in GCMs are the interactions between land and water surfaces, and the fluxes of energy, water and CO_2. The descriptions of these processes are based on small-scale field data or models which may not be valid for such large grid sizes.
Recently, regional circulation models (RCMs) have been developed. The grid cells of RCMs are in the order of 50x50 km^2. This makes RCMs more useful for application to relatively small regions. They use inputs from GCMs, but the resolution of an RCM for a particular region is better than that of a GCM.

Hydrological Models

Hydrological models are usually built for small-scale problems and for a particular purpose, for example for modelling of runoff or groundwater in a given locality, and hence can therefore vary enormously. They can be physically based models, conceptual models, or "black-box" models, and can either be deterministic or partly stochastic. As inputs, hydrological models use prescribed data, spatial analogue data, temporal analogue data or output data from GCMs (van Dam, 1999). Prescribed data may consist of for example present day precipitation, multiplied by a particular factor (multiplicative method) or the same data with an addition (additive method) (Brandsma, 1995). Spatial analogue data consists of data recorded at other locations, where the present climate could be the future climate of the location under consideration (Brandsma, 1995). Temporal analogue data is data recorded at a particular location over a period in the past in which the climate was wetter or warmer, and which is similar to that which might be expected during or after climate change in the catchment area under construction.

Coupling of GCMs and Hydrological Models

The main problem here is one of scale. As van Dam points out (van Dam, 1999), there is a discontinuity between the size of the GCM grid cells and the basin area for which the interactions between the atmosphere and the hydrological cycle are modelled by using a water balance approach. This means that there is a problem of regionalization or upscaling of the fluxes obtained by hydrological basin studies to be used as an input for GCMs, and/or of downscaling the results of GCMs to individual basins (Feddes et al., 1989; Feddes, 1995). A better understanding of the interactive processes that result in fluxes is therefore essential for more effective modelling.

Changes in Precipitation and Runoff

Throughout the relevant literature the published results for different regions vary considerably and they are rarely compatible, but general trends can be identified. The latest results in recent research are listed in the publication of the Intergovernmental Panel on Climate Change (van Dam, 1999). However estimates of the possible change in precipitation made with the aid of either GCMs or instrumental scenarios are extremely uncertain.
In general, the changes in precipitation and runoff differ from region to region. For instance in arid and semi-arid regions (e.g. parts of the USA, Russia, Australia, Africa and South America), a change in temperature of 1°C to 2°C and a decrease in precipitation by 10% could reduce annual river runoff by up to 40% or 70%. Compared to that, the changes range from a possible decrease of 6% to 12% to an increase of up to 20% in humid tropical regions.

Changes in River Discharge

The changes of discharge for particular rivers due to climate change are not easy to assess. There are many factors of the prevailing catchment characteristics to consider, e.g. potential evapotranspiration, soil moisture deficit (SMD), urban land use, and vegetation. Each factor contributes to uncertainty of a future prediction and the combination of many unclear factors will increase the uncertainty again. That is why most of the models, apart from the RHINEFLOW model by Kwadijk and Rotmans, only deal with precipitation and runoff. Discharge data estimated from precipitation and runoff results, obtained from GCMs, are based on many assumptions. Therefore results generated from discharge data, which were

Changes in Sediment Transport

Very little research has been done on alterations in sediment transport caused by climate change. Most of the research carried out on sediment transport has dealt with changes due to alterations in land use (e.g. Ferguson, 1991), and some research has been done regarding the consequences of climatic change (e.g. Collins, 1991). These studies focused on the comparison of historical data and data gained in recent fieldwork. For instance Collins (1991), in his work on climatic and glaeiological influences on suspended sediment transport from an alpine glacier, states that climate directly influences runoff. The process of how variations of flow during the ablation season are translated into suspended sediment transport depends on the areal interaction between the elements of the evolving basal drainage system with the glacier subsole. However, no work has been published yet on the direct effects of global warming on either bed load sediment transport or suspended load sediment transport. This may be due to the high degree of

uncertainty which would accompany any research on this topic.

Precipitation Pattern and Seasonality

In order to assess changes of sediment transport due to climate change, it is necessary to know the seasonal pattern of precipitation and consequently the pattern of runoff. Both are predicted to vary due to climate change. Therefore it is useful to know what these patterns look like at the present and how they might possibly evolve in the future.

Present patterns of precipitation are well known and can be easily assessed by using meteorological and hydrological records for any particular catchment. Usually the runoff pattern shows a seasonal character, but this might be different in the case of floods, as they vary considerably from region to region. The view of this pattern in this paper is limited to the three considered catchments. One also has to bear in mind that changes in land use, which may have a considerable influence on seasonality, are not considered for any of the three catchments.

COMPARISON OF THE EFFECTS OF CLIMATE CHANGE ON RIVERS IN SCOTLAND, GERMANY AND SWITZERLAND

With this background, the authors aim is to compare the potential effects of climate change on three river catchments of approximately equal size, differing in the geographical region they are situated in, in the climate zone and the character of flow. The three selected rivers are the River Spey in Scotland, the River Neckar in Germany and the River Alpenrhine in Switzerland.

THE RIVER SPEY IN SCOTLAND

The catchment of the River Spey is situated in the northeast of Scotland and has an area of 3,010 km^2 with a stream network length of 36,399 km, of which the main river comprises 120 km. The river flows in a predominantly northeasterly direction.

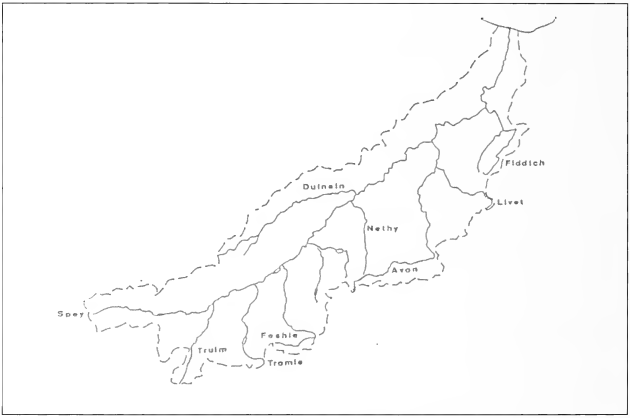


Figure 2: River Spey Catchment (North-East River Purification Board (1995))

from its source in Loch Spey, above Laggan to its entry into the Moray Firth at Tugnet, for approximately 157 km. The River Spey is the seventh in terms of length, the eighth largest in terms of mean annual flow and the ninth in terms of catchment area, in the British Isles. From the west there is only one major tributary, the River Dulnain. This drains the Monadliath Mountains. However, from the east and south of the main river there are a number of large tributaries, mainly draining the Cairngorm Massif, of which the River Avon is the largest, with a subcatchment of 1,390 km^2.

A feature unique to the River Spey in comparison to other major rivers in the northeast of Scotland is its rejuvenated character. That means that when land is uplifted, or the base level of a river is lowered for any reason, the river's erosive power is increased. The gradient down which it flows is increased and its powers of vertical erosion a re also increased. The river therefore becomes more active and is literally rejuvenated. The upper catchment to Newtonmore is relatively steep (1:225) as is the lower river below Grantown-on-Spey (1:380). The central part of the catchment is characterised by a broad meandering channel, wide flood plain, and

passage through Loch Insh, where the gradient (just 1:1200) is more typical of a lowland river.

Geology

Most of the Spey catchment is underlain by metamorphic rocks which are intruded in a number of places by granite plutons and are overlain at the northern end of the catchment by Devonian sandstone. For most of its length, the River Spey flows through a wide alluvial plain composed of silts, sands and water-borne pebbles. In the upland areas there are extensive beds of peat, some many metres thick.

Effects of climate change on the River Spey catchment

In the case of climate change leading to warming between 1°C and 2°C the estimated changes in precipitation over Scotland differ considerably. A comparison of the results of five different GCMs for the entire United Kingdom (Hulmes and Jones, 1989) concluded that the annual precipitation could increase between 20 mm and 200 mm, but that the seasonal distribution of this change was unclear. A rise in annual rainfall in this range could lead to an increase in runoff between 12% and 30% in the wetter regions of the United Kingdom, which include the south and the west of Scotland.

Although an estimate of an increase of 5% to 15% in annual rainfall is a likely scenario, there is a high degree of uncertainty in this estimate, and the bulk of the increase is likely to be concentrated in winter (Rowntree, 1990). A greater increase can be expected in the west and north than in the east and south. The estimate also depends heavily on the model used to link temperature and potential evapotranspiration, and it is certainly true that none of the scenarios with their results can be regarded as more realistic than any other (Arnell et al., 1990).

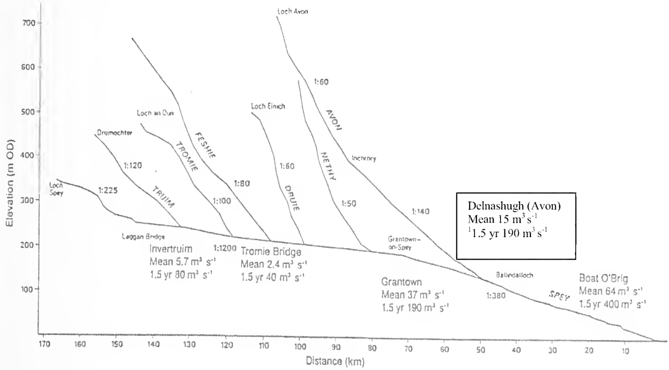


Figure 3: River Spey Catchment Gradients (North-East River Purification Board (1995))

In the north-east of Scotland where the Spey catchment is situated, the present-day rainfall pattern shows weak seasonality with a slight tendency towards more rain in the autumn and winter period (Black and Werritty, 1997). The consequence is that floods are approximately evenly distributed throughout the year, but in the case of large basins, such as the Spey catchment, more pronounced winter-dominated flooding is to be seen. For continuous warming, the future prediction (Arnell et al., 1990; Mansell, 1997) is that there will be an increase in runoff due to a significant increase in winter rainfall. In other words there will be more pronounced seasonality for the winter season and there may also be more concentrated periods of rain. The influence of snowmelt is almost insignificant.

THE RIVER NECKAR IN GERMANY

The catchment of the River Neckar is situated in the south-west of Germany, drains an area of 13,958 km^2, has a length of 367 km and flows almost without major diversions from south to north. The

River Neckar is one of the major tributaries to the River Rhine in its upstream part and mainly drains

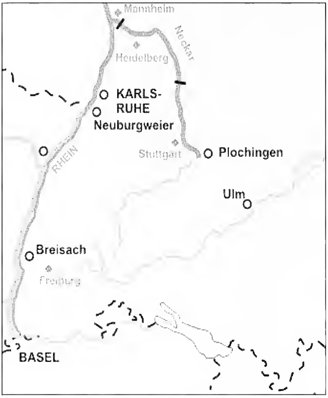


Figure 4: River Neckar, Germany (WSV Germany)

the mountains of the Black Forrest. The main tributary from the west is the River Enz and from the east there are the Rivers Fils, Rems, Murr, Kocher and Jagst. In order to obtain a catchment comparable with that of the River Spey, a part of the entire catchment was used. This was the part upstream of the gauging station at Plochingen with a catchment size of 3995 km^2. From its source in the middle of the moor Schwenniger Moos to the gauging station at Plochingen the River Neckar has a length of approximately 120 km. In the upstream part there is just one major tributary, the River Eyach from the south-east. The River Neckar has a main gradient of approximately 1:580 for its entire length. In its upstream part it is slightly steeper and at the confluence with the River Rhine it is slightly flatter.

Geology

In the upstream part of the catchment, the River Neckar is underlain by Jurassic limestone and shell limestone. Further downstream, between Tuebingen and Plochingen, this changes into Keuper, a regional type of marl, before returning again to shell limestone.

Most of the published studies on German hydrological regimes deal with the river Rhine. Because of the Neckar's geographical position close to the Rhine and the fact that it is one of the tributaries of the Rhine, the data of precipitation and runoff changes can be used. In the scenario study by Kwadijk and Rotmans (1995), using a climate assessment called ESCAPE coupled with a water balance model called RHINEFLOW, two main scenarios can be considered, HIGH (increase in precipitation) and LOW (decrease in precipitation). According to the LOW scenario, precipitation decreases from May to November which results in lower runoff in all seasons, because the increase in winter precipitation cannot compensate for the large decreases during the rest of the year. According to the HIGH scenario, the summer precipitation will also increase by 16% to 25% which will result in an increase in runoff throughout the entire year. These are two extreme scenarios for the changes in precipitation and runoff caused by a temperature rise of 1°C to 4°C (used in both scenarios). However, in the model used this leads to a more general result of an increase in discharge by 10% to 20% in winter and a change of discharge between -15% and +10% in summer.

The present pattern of rainfall and runoff shows that there are two main seasons, winter/spring and summer/autumn. The winter precipitation is partly stored as snow but the significance of this is not as high as for the Alpenrhine. Floods usually occur in late autumn and at the end of winter/beginning of spring. In the autumn the floods are just rain-fed, while melted snow will additionally feed the spring runoff. All in all, the winter and spring runoffs are higher than the summer and autumn ones. Increased temperature would lead to an increased runoff in winter, and a decreased runoff in spring and summer, of which the summer would be the driest season (Kwadijk and Rotmans, 1995).

THE RIVER ALPENRHINE IN SWITZERLAND

The River Alpenrhine is situated in the east of Switzerland, where it runs from south to north and drains an area of 6,122 km^2 on a length of 164 km, before its entry into Lake Constance. It runs predominantly in a northern direction and has its source in the Alps near the St. Gotthard Massif, where the river is formed by the confluence of the Vorderrhine and Hinterrhine. Most of the major tributaries come from the south and east and a few from the north and west. The gradient of the entire river is very steep.

Geology

The geology of the Alpenrhine is dominated by alternating deposits of gravel, sand, clay and peat as the non-uniformed filling of former lake basins. Further downstream it changes to young valley soils with fields of fluvial coarse gravel. The entire Alpenrhine is rich in sediments and thus in sediment transport.

The trends for the River Rhine are most pronounced for the River Alpenrhine (Kwadijk and Rotmans,1995). According to all scenarios, an increase in temperature will dramatically increase the volume of melt water. Also, winter precipitation, presently stored as snow, will be directly available for stream flow. These two facts when combined lead to an increase of 30% to 60% in winter discharge. The other effect is that this melt water volume will not be available in spring and

summer, thus decreasing stream flows by 10% to 15% during these periods.

In comparison with the catchments considered in Scotland and Germany, the Alpenrhine catchment shows clear seasonality for rainfall and for floods. At the present all four seasons are almost independent. In winter the precipitation is stored as snow and the temperatures are so low that the runoff is minimal. In late spring the runoff caused by precipitation is additionally increased by the volume of melt-water from the snow-melt. The summer and autumn differ in the amount of precipitation and runoff. Here, the changes caused by increased temperature will be very significant. The time during which the winter precipitation is stored as snow will decrease considerably, and therefore the immediate runoff will increase drastically (Kwadijk and Rotmans, 1995). As a consequence the volume of melt-water will decrease and will not be available anymore for the spring and partly also for the summer. Additionally, the precipitation will decrease in the summer and at the beginning of autumn. Basically, this means that the River Alpenrhine would change from a snow-melt fed river to a rain-fed river.

SUGGESTIONS FOR FURTHER RESEARCH

As the research is based on the knowledge available in 1999 it is first and foremost necessary to assess the latest set of predictions on climate change and therefore increase in temperature regarding the described problem. Secondly, more research is undoubtedly required to assess the influences of all the uncertain factors brought about by catchment characteristics. These characteristics include sediment supply, land use, vegetation, the final amount of runoff, and especially the discharge caused by precipitation. It is useful to test all these factors on their own to assess the real influence they may have on the change in sediment transport due to climate change. The results could then be tested to find the best solution to include the factors with a significant impact into the method, either as single factors or as possible combinations of factors. Another point is to compare the predicted results of changes in sediment transport with results from historic periods. For such comparison data records of sediment loads over a long period of time are required. A solution to the first two points mentioned above is the coding of a specific computer environment. This environment should enable more powerful and specific-oriented computation of the method.

ACKNOWLEDGEMENTS

The research for this article was carried out in the Department of Civil Engineering at the University of Glasgow and the Geography Department at the University of Glasgow, under the supervision of Prof Trevor B. Hoey, whose help and encouragement are gratefully acknowledged. I also wish to express my sincere thanks to Professor Alan Ervine, Department of Civil Engineering, University of Glasgow, for giving me the opportunity to attend the MSc Water Resource Engineering Management course. I am also indebted to the Bundesanstalt für Gewässerkunde (BAfG), Koblenz, Germany, namely Dr Disse, and to the Swiss National Hydrological and Geological Survey (SNHGS), Bern, Switzerland, namely C. Koch, for providing the author with sediment and discharge data for the River Neckar and the River Alpenrhine.

REFERENCES

Arnell, N.W., Brown, R.P.C. and Reynard, N.S. (1990) *Impact of climatic variability anchange on river flow regimes in the UK.* Institute of Hydrology Report No. 107. Wallingford: Institute of Hydrology, UK.

Berger, A. (Editor) (1981) Climatic Variations and Variability: Facts and Theories. NATO Advanced Study Institutes Series, Series C: Mathematical and Physical Sciences, Reidel, Dordrecht, 795 pp.

Black, A.R. and Werritty, A. (1997) Seasonality of flooding: a case study of North Britain. *J. of Hydrology*, **195** (1997): 1-25.

Brandsma, T. (1995) *Hydrological Impacts of Climate Change.* PhD thesis, Delft: Delft University of Technology, The Netherlands.

Chou, M.D., Peng, L. and Arking, A. (1982) Climate studies with a multi-layer energy balance model. Part II: The role of feedback mechanisms in the CO_2 problem. *J. Atmos. Sci.*, **39**: 2657-2666.

Clark, W.C. (1982) *Carbon dioxide review.* New York: Oxford University Press.

Collins, D.N. (1991) Climatic and Glaciological Influences on Suspended Sediment Transport from an Alpine Glacier. In: *Sediment and Stream Water Quality in a Changing Environment: Trends and Explanations.* Proceedings of the Vienna Symposium, August 1991, IAHS Publ. No. 203, pp. 3-12.

Dawson, A. (1992) *Global Climate Change.* Oxford: Oxford University Press.

Feddes, R.A., Menetti, M. and Kabat, P. (1989) *Modelling the Soil Water and SurfaceEnergy Balance in Relation to Climate Models.* European Coordination Group on Land Surface Processes, Hydrology and Desertification in Europe, Barcelona.

Feddes, R.A. (Editor) (1995) *Space and Time Scale Variability and Interdependencies in Hydrological Processes.* International Hydrology Series, Cambridge: Cambridge University Press.

Ferguson, R.I. (1991) Disentangling Land Use Effects on Sediment Yield from Year to Year Climatic Variability. In: *Sediment and Stream Water Quality in a Changing Environment: Trends and Explanations.* Proceedings of the Vienna Symposium, August 1991, IAHS Publ. No. 203, pp. 13-20.

Flohn, H. and Fantechi, R. (Editors) (1984) *The Climate of Europe: Past, Present and Future.* Reidel, Dordrecht, 356 pp.

Hulmes, M. and Jones, P.D. (1989) Climate change scenarios for the UK. Climate Research Unit, University of East Anglia. Report to the Institute of Hydrology.

IPPC (1985) International Conference on Climate Change and its Impacts. Villach, Austria.

In: van Dam, J.C. (Editor) (1999) *Impacts of Climate Change and Climate Variability on Hydrological Regimes.* International Hydrology Series, Cambridge: Cambridge University Press.

Kellogg, W.W. (1979) Influences of mankind on climate. *Annu. Rev. Earth Planet. Sci.*, **7**: 63-92.
Kwadijk, J. and Rotmans, J. (1995) The Impact of Climate Change on the River Rhine: a Scenario Study. *Climatic Change*, **30**: 397-425.
Manabe, S. (1983) Carbon dioxide and climatic change. *Adv. Geophys.*, **25**: 39-82.
Manabe, S., Wetherald, R.T. and Stouffer, R.J. (1981) Summer dryness due to an increase of atmospheric CO_2 concentration. *Climate Change*, **3**: 347-385.
Mansell, M.G. (1997) The effect of climate change on rainfall trends and flooding risk in the West of Scotland. *Nordic Hydrology*, **28** (1): 37-50.
Mitchell, J.F.B. (1983) The seasonal response of a general circulation model to changes in the CO_2 and sea temperatures. *Q. J. Meteorol. Soc.*, **109**: 113-152.
Mitchell, J.F.B. (1986) On modelling the effects of CO_2 on climate. In: A. Gazhi and R. Fantechi (Editors)
Watts, R.G. (1980) Climate models and CO_2 induced climatic changes. *Climatic Change*, **2**: 378-408.
WMO (1986) Report on the International Conference on the assessment of the role of carbon dioxide and other greenhouse gases in climate variations and associated impacts. ICSU, UNEP ,WMO , Villach 9-15 Oct. 1985, WMO-No.661, Geneva. of CO_2 with an atmospheric general circulation model coupled to a simple mixed-layer ocean model. *J. Geophys. Res.*, **89** (D9): 9475-9503.
Washington, W.M. and Meehl, G.A. (1984) Seasonal cycle experiments on the climatic effect due to a doubling concentration. *J. Geophys. Res.*, **88** (C11): 6600-6610.
Current Issues in Climate Research. Reidel, Dordrecht, 228-239.
North-East River Purification Board (1995) River Spey: catchment review.
Ramanathan, V. (1981) The role of ocean-atmosphere interactions in the CO_2 climate problem. *J. Atmos. Sci.*, **38**: 918-930.
Rowntree, P.R. (1990) Estimates of future climatic change over Britain. Part 2: Results. *Weather*, **45** (2): 38-42.
Van Dam, J.C. (Editor) (1999) *Impacts of Climate Change and Climate Variability on Hydrological Regimes*. International Hydrology Series, Cambridge: Cambridge University Press.
Washington, W.M. and Meehl, G.A. (1983) General circulation model experiments on the climatic effects due to a doubling and quadrupling of carbon dioxide

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 79-85.

GROWTH RATE OF AILSA CRAIG SLOW-WORMS *ANGUIS FRAGILIS*: PREY PREFERENCE AND TEMPERATURE EFFECTS

Cara Lavery, J.R. Downie[1] and Suzanne R. Livingstone

Institute of Biomedical and Life Sciences, Division of Environmental and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ.

[1]J.R. Downie@bio.gla.ac.uk (author for correspondence)

ABSTRACT

Slow-worms are abundant at lower altitudes on the island of Ailsa Craig (Firth of Clyde). They attain remarkable lengths: one male at 51.8 cm is the longest recorded in the UK. Most are found under metal and wooden sheet refuges, where congregations of about 40 individuals are common. Continuous temperature records in these refuges show significantly higher than ambient day-time temperatures. Prey choice experiments showed no size preference for slugs over a range of about 0.5-2.5g. Slow-worms kept at 27-28°C ate more and grew faster than slow-worms kept at 18°C.

Keywords: Ailsa Craig, slow worm, *Anguis fragilis*, growth and temperature, prey preference

INTRODUCTION

The slow-worm *Anguis fragilis* is probably one of the UK's commonest reptiles. There are no reliable population estimates for UK reptiles, but recorded sightings of slow-worms show a widespread distribution with most records in England being in the south, especially the south east, but in Scotland mainly in the south-west (Beebee and Griffiths, 2000). The slow-worm's fossorial habits contribute to our relative lack of knowledge both of this reptile's distribution and its ecology and habits. To understand this animal better, we need a good study site. One such is the island of Ailsa Craig which lies in the Firth of Clyde, 16 km west of Girvan. Ailsa Craig was designated a site of Special Scientific Interest in 1984, then a Specially Protected Area in 1990 and has now (2004) become a Royal Society for the Protection of Birds Reserve by agreement with the owner, the Marquis of Ailsa. The island's main interest is the vast populations of sea-birds which nest on its cliffs, but since a rat eradication programme in the early 1990s, it has become apparent that the island supports a considerable variety of fauna and flora (Zonfrillo, 1994). The first report of slow-worms on the island dates from the 1800's (Lawson, 1888); they were severely affected by the rat population, but, since the eradication, Zonfrillo (2000; personal communication) has noted not only that slow-worms are abundant but also that some individuals have attained remarkable sizes.

The aims of the work reported here were:

- To assess the sex ratio and sizes of slow-worms found in refuges on Ailsa Craig.
- To measure the temperature in slow-worm refuge sites
- To test prey size preference in slow-worms
- To measure slow-worm growth rate at different temperatures

MATERIALS AND METHODS

Visits to study site Ailsa Craig was visited on 17^{th} June, 22^{nd} July, 28^{th} August and 11^{th} October 2003. Each visit required a boat trip of 1.5h there and back, with 2-3h field-work on the island. Round much of Ailsa Craig, sheer cliffs face directly on to the sea, but on the east of the island, there is a relatively flat raised beach, rocky and shingly close to the sea, but well vegetated further on shore, rising steeply to a higher level. It is on the vegetated area that the light-house, disused quarry works and mainly ruined village are located (Fig. 1). Around the only habitable cottage, Dr Bernard Zonfrillo has placed a number of corrugated iron and plywood sheets to act as slow-worm refuges. Each visit, these sheets were lifted to sample slow-worms.

Slow-worm sampling An original aim of this study was to estimate population size, using the technique of mark and recapture. Since there is no effective marking technique for slow-worms, we hoped to use photographs of the unique head parietal pattern to identify individuals (Riddell, 1997): unfortunately, our camera had insufficient resolution and this aim had to be abandoned.

Since the number of slow-worms under each sheet could be around 30-40, some fully exposed, some half-burrowed, it was not practicable to count total numbers in each refuge: they lie closely entwined and can burrow remarkably quickly. Our method therefore was to lift a sheet quickly and pick up as many slow-worms as we could and transfer them to a bucket. We took them for measuring, then returned and collected a second sample from the same refuge. All slow-worms were replaced under their original refuges after measuring, except those taken to the laboratory for feeding experiments (see later). In addition to sampling regularly under

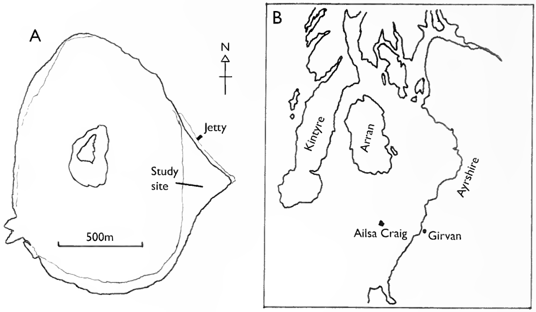


Fig. 1 Study site map and location (re-drawn from Zonfrillo, 1994). A: sketch map of Ailsa Craig, showing location of study site on flat area to south of jetty; B: location of Ailsa Craig.

the metal and wooden refuges, we used a line transect technique to assess the presence of slow-worms further from the cottage.

Slow-worm measuring and sexing On Ailsa Craig, slow-worms were weighed in bags using a Pesola spring balance accurate to 0.1g; in the laboratory they were weighed in closed polythene tubs using a digital balance to 0.01g. To measure length, slow-worms were straightened and held straight by one observer (this is not easy!) while the other assessed length to 0.1 cm using a meter stick. Individuals were sexed by the criteria of Beebee and Griffiths (2000): females have a dark dorsal stripe and are generally dark in colour; males lack the dorsal stripe and have a lighter uniform colour. Juveniles are not easily distinguished and even some larger individuals were unclear.

Field temperatures Gemini data loggers ('Tinytalks') were used to measure field temperature from 17th June to 11th October. These loggers are accurate to 0.1°C and were set to measure temperature every 2h i.e. 12 times a day. Loggers were sealed in polythene bags to protect them from excessive moisture. One was located under a corrugated iron refuge; another under a plywood refuge; the third was placed in a sheltered but not shaded site on the ground surface near the cottage. The information recorded was later downloaded onto a computer and analysed using Gemini software.

Laboratory experiments Samples of slow-worms from Ailsa Craig were taken to our laboratory at the University of Glasgow as follows: 17th June – 13 slow-worms, varying sizes, both sexes (returned 28th August); 22nd July – 4 slow-worms (returned 11th October); 28th August – 10 slow-worms (returned 11th October).

Each slow-worm was maintained individually in a plastic tank 34x18x17 cm with a tight-fitting lid containing narrow air slits. Tanks were filled to 8-10 cm deep with moist peat. A water bowl was placed on each tank, the top flush with the peat surface. The peat was re-wetted weekly.

To feed the slow-worms, slugs were collected regularly from allotments, gardens and damp walls round the west end of Glasgow. We did not attempt to discriminate between species of slugs. Runham and Hunter (1970) note the difficulties of distinguishing the species of slugs on external characteristics: from their descriptions, *Agriolimax reticulatus* is likely to have been the commonest species in our collections.

Slow-worm tanks were kept in two rooms a) an unheated laboratory with natural lighting; temperature about 19°C. b) a temperature-controlled room at 27.5-28.5°C, with a 12h light:dark cycle.

Prey size preference experiment The 13 slow-worms collected on 17th June were fed twice a week for 5.5 weeks with one large (>2g), three medium (1-2g) and three small (<1g) slugs. Before each feed, slow-worms were measured and the tanks checked for uneaten slugs. The summer was unusually hot and dry for Glasgow, and slugs were sometimes very hard to find. Occasionally, therefore, it was not possible to provide the normal slug ration. This experiment was in the 19°C laboratory.

Temperature and growth experiment The 10 slow-worms collected on 28th August were divided into two groups, one kept in the 19°C laboratory and the other in the 27-28°C room. Each slow-worm was fed 8-9g of slugs (randomly mixed sizes) twice a week. Before each feed, slow-worms were measured and the tanks checked for uneaten slugs which were weighed collectively and replaced in the tank. During this experiment, there was cooler, damper weather and the slug supply was adequate for our needs.

RESULTS

Population data Lengths and weights of animals in the June-August samples are shown in Table 1 (too few were measured in October for analysis).

Table 1 Morphometric data on Ailsa Craig slow-worms found under refuges. Lengths and weights given as mean ± SD with range in brackets.

Date		Males	Females
17/6/03[1]	N	23	10
	Length	38.0 ± 7.2	39.3 ± 7.4
	(cm)	(22.0- 1.8)	(24.1 -46.1)
	Weight	27.5± 10.9	29.0 ± 11.8
	(g)	(12.0– 9.3)	(6.5 – 44.5)
22/7/03[1]	N	14	10
	Length	35.6 ± 8.0	35.2 ± 8.9
	(cm)	(22.3–_6.4)	(21.1– 42.9
	Weight	30.7± 12.7	25.7 ± 14.4
	(g)	(5.0– 52.0)	(4.5 – 41.5
28/8/03[1]	N	11	19
	Length	38.0 ± 7.0	33.3 ± 10.5
	(cm)	(26.6– 7.3)	(18.9– 6.4)
	Weight	30.6± 13.1	22.4 ± 13.4
	(g)	(14.1– 8.3)	(3.3 – 44.8)

[1] 17/6/03 Two males excluded from length and weight analysis because tails were shed on capture; 22/7/03 two males and one female excluded; 28/8/03 one female excluded.

The sex ratio in the June-August samples was significantly biased towards males in June ($X^2 = 5.12$; $P < 0.05$) but the ratios were not significantly different from 1:1 in the other months. The lengths and weights of the animals were very variable, as can be seen from the high standard deviations, and means were considerably affected by the proportion of smaller slow-worms sampled. The longest slow-worm found was 51.8cm (weight 46.5g) and the heaviest 52.0g (length 46.4cm), both males. We found no evidence for a difference in the length-weight relationship between males and females (data not shown), but our sample size was too small to detect any fine differences.

Slow-worms were examined for signs of tail regeneration (the regenerating tail has a blunt tip): over the four visits we found 8 males and only two females with regenerating tails (from their sizes, these were most likely different animals except for two males).

All but a few of the measured slow-worms were located under metal or wooden sheets in the cottage area. We attempted to assess slow-worm distribution by looking under rocks, within a metre of a 50 metre line extended in three random directions from the cottage. However because of the highly aggregated nature of the population, this method was not successful, depending entirely on whether or not the transect included a good refuge. Another method was to lift rocks randomly in a walk away from the cottage: this at least showed that slow-worms did occur as far as 200 metres south of the cottage, but only some rocks could be lifted, so this method could not be properly quantitative.

Habitat temperature records Temperature data collected by the Tinytalk loggers are shown in figure 2 and an analysis in Table 2. Daily temperature fluctuations were greatest under the metal sheet, exceeding 40°C on 8 occasions, and dropping to between 10 and 15°C most nights.

Under the plywood sheet, the temperature never exceeded 40°C, but did exceed 30°C on 9 occasions, also dropping to between 10 and 15°C at night. By contrast, even in what was an unusually warm dry summer, the logger on the grass surface only once recorded a day-time temperature over 25°C, and daily fluctuations were characteristically of the order of 5-10°C only.

Table 2 shows mean temperatures at different times of day in each of three months measured at the three different sites. Not unexpectedly, night temperatures were similar at all three sites and remained at a similar level through most of the summer, only beginning to decline in later September. The biggest inter-site and inter-month differences were in the period most influenced by solar radiation, 08.00-16.00h, with mean temperatures in the refuges eonsiderably higher than on the grass surface (metal sheet: 6-7°C; plywood: 3.5-4.5°C July and August), even in September (3-3.5°C).

The middle time period, 16.00-24.00h, showed only small differences between the sites: with the site east-facing and in the shade of a steep hill, temperatures drop quickly once direct sunlight has passed.

Table 2 Analysis of three site temperature records: data are mean temperatures (°C ± SD) in different months at different times of day. Recordings were at 2h intervals each day of each month. Metal: metal sheet; Plywood: plywood sheet; Grass: grass surface.

Time range Month	Site Metal	Plywood	Grass
July			
08.00-16.00h	22.9 ± 7.9	21.0 ± 5.3	16.6 ± 2.3
16.00-24.00h	17.4 ± 13.7	17.4 ± 3.8	15.9 ± 0.4
24.00-08.00h	13.6 ± 1.6	13.7 ± 1.7	14.0 ± 1.4
Aug.			
08.00-16.00h	24.1 ± 8.0	20.8 ± 4.6	17.1 ± 2.4
16.00-24.00h	18.3 ± 5.3	16.6 ± 3.7	16.5 ± 2.2
24.00-08.00h	13.1 ± 2.1	12.6 ± 2.3	14.3 ± 1.7
Sept.			
08.00-16.00h	18.1 ± 5.3	17.4 ± 5.1	14.5 ± 2.6
16.00-24.00h	14.0 ± 3.1	13.1 ± 3.5	13.5 ± 2.0
24.00-08.00h	11.6 ± 2.3	10.7 ± 2.7	12.3 ± 2.0

Prey size preference Early during this experiment, one slow-worm escaped and was not re-captured. We therefore obtained data for prey preference from 12 slow-worms, ranging in weight from 7-49g (Table 3). The largest slow-worms tended to eat all or nearly all the prey items offered, whereas smaller slow-worms ate 70-90% of prey. Using Spearman's rank order correlation, we found significant positive relationships between proportion of prey items eaten and slow-worm weight for each prey size class (large: $r = 0.61$, $P < 0.05$; medium: $r = 0.59$, $P < 0.05$; small $r = 0.78$, $P < 0.01$). There was no evidence for slow-worms showing prey size selectivity but there was evidence for differences in total prey taken, related to slow-worm size. It is worth noting that size change over the 5.5 weeks of the experiment was very variable between individuals but rather small for the population as a whole, especially in length (mean ± SD percentage change for the population in weight was 3.2 ± 13.3; length 0.4 ± 2.4). The high standard deviations are the result of some individuals reducing in their weight or length while others increased.

Temperature and growth Over the 5 weeks of the experiment, the mean size changes for the two temperature groups are shown in Table 4.

Table 3 Dimensions at end of trial of slow-worms used in prey size preference experiment.

Animal number	Weight (g)	Length (cm)
1	40.1	46.1
2	49.4	49.4
3	14.8	33.8
4	7.6	24.7
5	34.8	42.5
6	12.8	32.5
7	31.2	42.9
8	27.5	42.5
9	32.2	44.1
10	40.3	43.2
11	15.8	34.4
12	24.2	38.4

Table 4 Size changes in slow-worms kept at two temperatures for 5 weeks and fed 16-18 g slugs each week.

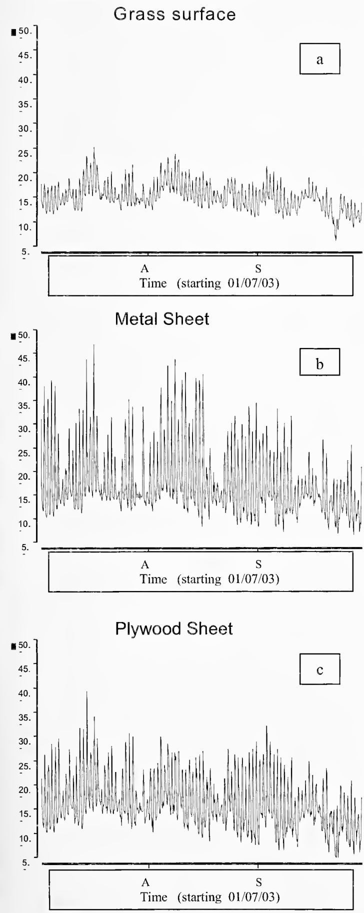
Temp. °C	n	%size change (mean ± SD) Wt (g)	Lgth (cm)
19	5	-1.9± 12.5	1.2± 1.2
27-28	5	165.7± 62.2	9.3± 11.2

Table 5 Slug consumption in slow-worms kept at two temperatures for 5 weeks: data as mean ± SD. Total slugs available, proportion of slugs consumed (%), and daily consumption (g).

Temp. °C	n	slugs available (g)	slugs cons. (% wt)	daily cons. (g)
19	5	67.3± 1.0	75.0 ± 8.4	1.4 ± 0.2
27-28	5	72.9± 4.9	96.7 ± 3.5	2.0 ± 0.2

At the lower temperature, slow-worms grew hardly at all. At the higher temperature, growth was considerable but very variable. Weight tended to fluctuate considerably from week to week, probably relating to ingestion of food (and the relatively slow digestion rates in these ectothermic animals). Length was probably the more reliable measure of tissue growth. Figure 3 shows the relationship between length change and initial length at the two temperatures. Although the sample size is

Fig. 2 Daily fluctuation in temperature records (y axis), time starting (x axis, A = August, S = September) at three sites taken from Tinytalk dataloggers.
a) grass surface b) metal sheet c) plywood.



too small for statistical analysis, it seems clear that the larger slow-worms changed little at both temperatures, whereas the higher temperature allowed small slow-worms to grow rapidly.

Slug consumption was very different in the two temperature groups: Table 5 summarises the results. Each slow-worm was fed a very similar slug ration twice a week, but if the slugs remaining from previous feeds exceeded the normal ration (8-9g), no extra slugs were provided. This only happened with the 19°C group, leading to a slightly lower mean ration over the 5 weeks. Daily consumption was significantly lower in this group, as was the percentage of ration consumed. On every occasion, slugs were left unconsumed by the slow-worms in this group, showing that the ration was in excess of their consumption capacity. However, in the 27-28°C groups, all slugs had been consumed on a total of 16 occasions (3.2 occasions per slow-worm over 9 samples), suggesting that this group could have consumed a few more slugs.

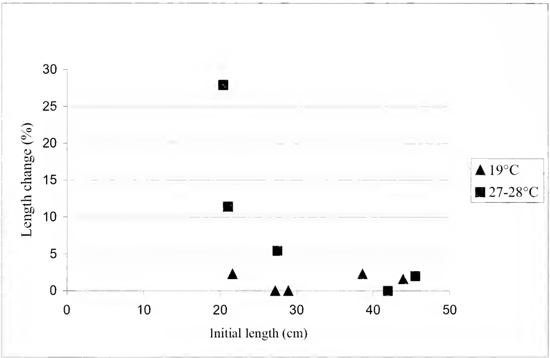
DISCUSSION

There are very few recent studies on the ecology of British slow-worms (Beebee and Griffiths, 2000, cite only four since 1980) and even fewer based in Scotland. This is the first study on the population based on Ailsa Craig, drawn attention to by Zonfrillo (2000).

Beebee and Griffiths (2000) note that mainland slow-worms can reach 40.0 cm long, but that longer individuals have been reported from islands, with the "record" a 48.9 cm specimen from Portsmouth (Fairfax, 1965). However, Zonfrillo (2000) found one even longer in Ailsa Craig (49.0 cm) and we confirm the exceptional size of some Ailsa Craig individuals. One male was 51.8 cm (46.5 g) and seems to be the longest slow-worm reported from the UK. Furthermore, 50% of our June sample were over 40 cm in length. It is unclear what factors lead to these exceptional sizes. Longevity, abundant food resources and genetic factors may all be involved. Beebee and Griffiths (2000) note that females are longer than males at equivalent ages in some but not all populations. We were not able to determine ages, but did examine the length – weight relationship in the two sexes. There was no significant difference, but sample sizes were small and further data would be worth collecting.

Previous work (Patterson, 1990; Avery, 1995) has shown that slow-worms in the field are generally found under refuges such as pieces of metal, wood or rocks. This was also the case on Ailsa Craig, though it is impossible to

Fig. 3 Relationship between slow-worm length at the start of the experiment and length change after 5 weeks when kept at two temperatures, ▲ = 19°C and ■ = 27-28°C.



tell how many slow-worms were hidden in burrows when we took our samples. A mark-recapture study using individual head patterns as the 'mark' might answer the question. We also do not know how slow-worm location changed with time of day, since all our samples were taken around mid-day.

Most lizards bask in the sun to raise body temperature above ambient in order to promote their foraging speed and also digestive rate. On Ailsa Craig, common lizards, *Lacerta vivipara*, can be found basking on rocks near the shore (personal observations). The aggregation of slow-worms under refuges during the day suggests that they are mainly nocturnal foragers, which would correlate with the active time of their main prey, slugs, snails and earth worms (Luiselli, 1992). Slow-worms may use refuges to increase body temperature which would in turn promote food digestion and growth. Our temperature loggers showed that refuge temperatures during the middle of the day were well above normal surface temperatures. Indeed, on very hot days, temperatures under the metal sheet exceeded 40°C. In this context, it is interesting that Beebee and Griffiths (2000) report that slow-worms leave refuges when the temperature exceeds 35°C.

In our laboratory experiment on slug size preference using small, medium and larger slugs, we found no preferences, even in smaller slow-worms. However, we did not use very large slugs nor very small slow-worms, so there may be a preference related to slow-worm size outside the range we used.

Our second laboratory experiment, with slow-worms at two different temperatures and prey available in excess showed higher prey consumption at the higher temperature and significant growth, particularly in smaller slow-worms. This supports the adaptive value for slow-worms of seeking warm temperature refuges.

The abundance of slow-worms on Ailsa Craig makes this a particularly good location to study their ecology. Elsewhere, they are regarded as widespread but rarely common (Smith, 1991) and recent records for both common lizards and slow-worms in Scotland are very patchy (Bowles, 2002). A study with more field time on Ailsa Craig could be very valuable.

ACKNOWLEDGEMENTS

We thank the Blodwen Lloyd Binns Bequest for a grant which permitted travel to Ailsa Craig; Scottish Natural Heritage for permission to remove slow-worms temporarily from Ailsa Craig; Bernie Zonfrillo for showing us the island and sharing his vast knowledge of its natural history; Chris McLaren, Liz Miller and Jenny Barr for help with

fieldwork and slug measuring; Kelvinside Allotments Association for access to collect slugs.

REFERENCES

Avery, R.A. (1995). Reptiles and amphibians on Mendip. *Proceedings of the Bristol Natural History Society*, 55 55-61.

Beebee, T.J.C. and Griffiths, R.A. (2000). *Amphibians and Reptiles: a natural history of the British Herpetofauna.* Harper Collins, London.

Bowles, F.D. (2002). Are common lizards increasing their range in Scotland? *Herpetological Bulletin* 80, 4-6.

Fairfax, R.A. (1965). Very large English slow-worm. *British Journal of Herpetology* 3, 229.

Lawson, R. (1888). *Ailsa Craig: its history and natural history*. Paisley.

Luiselli, L. (1992). The diet of the slow-worm, *Anguis fragilis* Linnaeus 1758, in the Tanisio Forest (Carnic Alps, N.E. Italy). *Herpetozoa* 5, 91-94.

Patterson, J.W. (1990). Field body temperatures of the lizard *Anguis fragilis*. *Amphibia-Reptilia* 11, 295-306.

Riddell, A. (1997). Identifying individuals: which slow-worm is which? In: Riddell, A. (editor): *The Slow-worm*:. Kent Reptile and Amphibian Group. Ps 15-16.

Runham, N.W. and Hunter, P.J. (1970). *Terrestrial slugs*. London, Hutchinson & Co.

Smith, N.D. (1991). *The ecology of the slow-worm (Anguis fragilis L) in Southern England.* University of Southampton, unpublished M.Phil. Thesis.

Zonfrillo, B. (1994). The flora and fauna of Ailsa Craig. *Glasgow Naturalist* 22, 304-347.

Zonfrillo, B. (2000). Large slow worm *Anguis fragilis* from Ailsa Craig, Ayrshire. *Glasgow Naturalist* 23(5), 59.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 87-88.

A RICH BOTANICAL STRIP AT SHETTLESTON, EAST END OF GLASGOW

P Macpherson[1] & EK Lindsay[2]
15 Lubnaig Road, Glasgow G43 2RY[1]
18 Monreith Road, Glasgow G43 2NY[2]

INTRODUCTION

Our botanical interest in the Shettleston area began in 1999. One of the authors had dropped off members of the family in Glasgow city centre and was on his way to record in South Lanarkshire, when he became aware of a stretch of interesting looking habitats to the north of Shettleston/ Old Shettleston Road in the east end of Glasgow. He did not proceed further that day and between then and 2003, a further 10 visits have been paid, enabling the area to be recording in detail.

Five sites were identified as being of botanical interest. Three are to the west of the area off Shettleston Road and two smaller ones further east off Old Shettleston Road. They are shown as shaded areas in Fig. 1. The sites are composed mainly of a series of abandoned industrial complexes, ranging from a well-wooded scrubby area to parts, which are almost bare. In total they make up approximately 103,600 square metres, of which approximately 99,600 sq. m. are in the Ordnance Survey grid square 26/6364 and 4,000 in 6464, both in Lanarkshire (VC 77).

RECORDS

We recorded a total of 266 plant taxa, categorised as on Fig. 2. One hundred and sixty are regarded as native plants: of these 17 were grasses, 14 trees, four rushes, two wood-rushes, four ferns and one sedge.

The most attractive visually are Common Spotted-orchid (*Dactylorhiza fuchsii*), Northern Marsh-orchid (*D. purpurella*) and Broad-leaved Helleborine (*Epipactis helleborine*) - a plant surprisingly common in Glasgow (Dickson *et al.* 2000). There is a colony of white-flowered Herb-Robert (*Geranium robertianum*). Hybrids included Oxford Ragwort x Groundsel (*Senecio squalidus* x *S. vulgaris*) - a new vice-country record (VCR), the eyebrights *Euphrasia arctica* x *E. nemorosa* and *E. confusa* x *E. nemorosa* (four other records) and three willows *Salix aurita* x *S. cinerea*, *S. caprea* x *S. cinerea* and *S. cinerea* x *S. viminalis*. The rarest grass was a sub-species of Red Fescue- Chewing's Fescue (*Festuca rubra* ssp. *commutata*) for which there are only four other records.

Alien records totalled 106, with only 13 classified as accidental and 93 as hortal (ie arrived in the study area by intentional human activity), the plant status nomenclature being as per Macpherson *et al* (1996). Accidental introductions included the hawkweed *Hieracium consociatum* (a segregate of *H. acuminatum*) growing in a large clump (VCR). The hortal group included 11 cotoneaster taxa, the rarest of which was Creeping Cotoneaster (*Cotoneaster adpressus*) the first definite VCR. There is a large established colony of Garden Honeysuckle (*Lonicera* x *italica*)- VCR (probably first for Scotland) and a smaller one of Tartarian Honeysuckle (*L. tatarica*)- the second VCR. Other VCRs were Atlas Poppy (*Papaverum atlanticum*),a seedling of Swamp Cypress (*Taxodium distichum*), and Intermediate Bridewort (*Spiraea rosalba* nothovar *rubella*). Four stonecrops are established, including *Sedum* "Autumn Joy" (second VCR), and Himalayan Knotweed (*Persicaria wallichii*) is another second record. Third records for the vice-county are Japanese Spiraea (*Spiraea japonica*), Red-leaved Rose (*Rosa ferruginea*) and Firethorn (*Pyracantha coccinea*).

Overall there are eight taxa of willow and two poplars, all either native or established and three whitebeams, including *Sorbus croceocarpa*. Surprisingly, the only alien grass was Bread Wheat (*Triticum aestivum*).

DISCUSSION

For its size the area is comparable to other rich botanical sites in which intensive recording has been carried out. The combined area is only about 10.4% of a 1km square and yet 266 taxa were noted. On the abandoned industrial site at Gartcosh 197 plants were recorded in an area of c. 60% of a 1km square (Macpherson 2001), at "Lanarkshire's Nose" in the extreme north-west of the vice-county again 266 taxa were recorded in an area comprising 39% of a 1km square (Macpherson & Teasdale 1986) and at Bogleshole where a full 1km square was surveyed 273 taxa were recorded (Macpherson *et al.* 2001). Seven of the plants seen were first, three second and three third records for the vice-county.

ACKNOWLEDGEMENTS

We are grateful to the following for help with identification; Messrs EJ Clement, RD Meikle, DR McKean, Dr AJ Silverside and Professor CA Stace.

REFERENCES

Dickson, JH, Macpherson, P & Watson, KJ (2000). *The Changing Flora of Glasgow*. Edinburgh University Press, Edinburgh.

Macpherson, P & Teasdale, E (1986). Plant recording at the tip of Lanarkshire's Nose. *Glasgow Naturalist* 21, 201-214.

Macpherson, P, Dickson, JH, Ellis, RG, Kent, DH & Stace, CA (1996). Plant Status Nomenclature. *BSBI News* 72,13-16.

Macpherson, P (2001). An unusual assemblage of plants at Gartcosh, Lanarkshire (VC 77). *Glasgow Naturalist*, 23, 22-23.

Macpherson, P & Lindsay, EK&DB (2001). Plant recording at Bogleshole. *Glasgow Naturalist* 23, 24-25.

Figure 1. The sites of recording in Shettleston are shown as shaded areas.

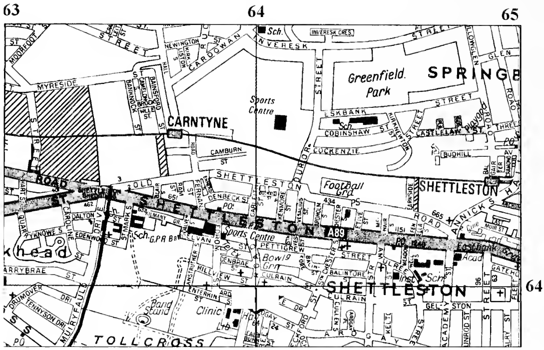
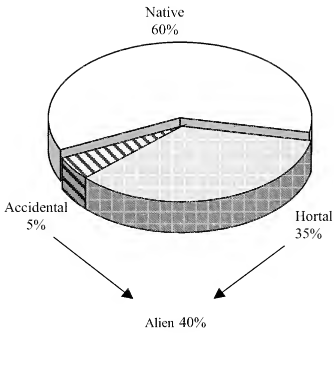


Figure 2. The native and alien plants recorded. Status of plants (N = 266).



Glasgow Naturalist 2004. Volume 24. Part 2. Pages 89-91.

DISTRIBUTION AND POPULATION STATUS OF THE OTTER (*LUTRA LUTRA*) IN THE LOCH LOMOND AREA.

D. J. McCafferty
Department of Adult & Continuing Education
University of Glasgow,
St Andrew's Building, 11 Eldon Street, Glasgow G3 6NH
d.mccafferty@educ.gla.ac.uk Tel: 0141 330 1835 FAX: 0141 330 1821

ABSTRACT

Loch Lomond is thought to be an important site for otters (*Lutra lutra*) as it is the largest area of freshwater in mainland Britain and has one of the most diverse fish communities of any area of freshwater in Scotland. Between 2001 and 2003 a spraint survey indicated that otters were widespread throughout Loch Lomond and its tributaries and there had been an increase in the proportion of tributaries with otters present since the late 1970s. The variety of prey in the loch and the suitability of habitat suggest that the area is highly favourable for otters at the present time. Continued monitoring of the otter population is recommended, given the region's new status as Scotland's first National Park and concerns about human activity in the area.

INTRODUCTION

Loch Lomond is the largest area of freshwater in mainland Britain, it has one of the most diverse fish communities of any area of freshwater in Scotland (Adams 1994) and therefore it is likely to be an important ecosystem for the otter (*Lutra lutra*). Otters have been recorded in Loch Lomond since the 1800s (Gibson 1984; Gibson and Mitchell 1986) and surveys of Scotland in the past three decades found signs of otters on most tributaries and several areas of the loch shore (R. Green unpublished data).

Within the past 30 years otter populations in Scotland and throughout Europe have been expanding, reversing a major decline that began in the 1950s. The previous decline of the otter has been attributed to a variety of causes including hunting and persecution, accidental mortality, the release of persistent contaminants, a reduction in water quality, habitat loss and increased disturbance (Green and Green 1997). Although the favourable status of otter populations at the present time would indicate that many of these factors have been reduced, continued monitoring of otters is required to avoid future threats throughout its range.

Loch Lomond and the Trossachs was established as Scotland's first National Park in July 2002. Although this may provide an extra level of protection for the environment in the region there is justifiable concern about levels of pollution in the loch and the effects of increasing recreational pressure on the area (Bannan *et al.* 2001; Mitchell 2001). The aim of this study was therefore to determine how widely distributed otters are within the Loch Lomond area and identify suitable sites for future monitoring of the population.

METHODS

The presence of otters was determined by searching for signs (spraints, tracks and prey remains) between October 2001 and December 2002. Road bridges across the main tributaries of Loch Lomond were taken as sampling points and an area of approximately 200 m on either side of each bridge was searched. Searches were stopped when signs of otters had been found. Four areas of the loch shore were also systematically searched each month from January to December 2002 to determine the year round presence of otters using the loch. The sites were distributed along the Eastern shore of the loch and were located at: Endrick mouth (NS 427877), Ross Point (NS 375956), Inversnaid (NN 339075) and Ardleish (NN 327153). A length of approximately 1 km of shoreline was searched for signs. Spraints were collected for future analysis and to prevent duplicate recording between months. In addition, signs of otters were recorded opportunistically on visits to the loch between October 2001 and May 2003.

The occurrence of otters in the Loch Lomond area was compared with previous records collected during the National Otter Surveys of Scotland in 1977-9, 1984-5 and 1991-4 (R. Green unpublished data).

RESULTS

Otters were found to be widespread throughout Loch Lomond and its tributaries (Fig. 1). Signs of otters were recorded on all major rivers entering the loch and on the river Leven leaving the loch (Table 1). Otter spraints and tracks were observed in a number of shore locations, including the northern shore of the island Inchcailloch (Fig. 1).

Table 1. Loch Lomond tributaries that were searched for presence of otters between October 2001 and December 2002. All locations showed signs of spraint except Fruin Water which showed tracks. All had been surveyed previously except for Arklet burn.

Location	Grid Ref.	Date
River Falloch	NN 319188	11.04.02
Inveruglas water	NN 320093	18.12.02
Arklet burn	NN 354094	29.06.02
Douglas water	NS 345979	13.06.02
Finlas water	NS 354881	12.10.01
Fruin water	NS 356857	12.10.01
Luss water	NS 358926	12.10.01
River Leven	NS 393792	25.07.02
River Endrick	NS 473874	22.05.02

Fig. 1. Location of otter signs found at Loch Lomond and its tributaries between October 2001 and May 2003. Signs of otters were recorded from sytematic searches at four main shorelines (○) and on main tributaries (•). Opportunistic records of spraints are also shown (▲). The geographical location of Loch Lomond is given (□).

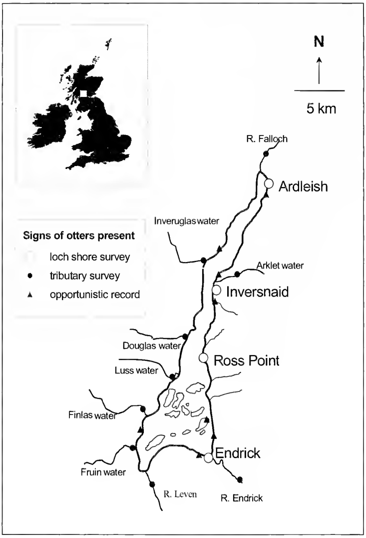
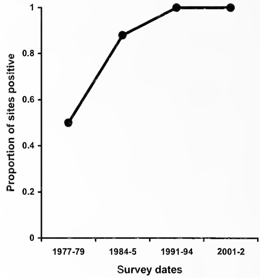


Fig. 2. Proportion of Loch Lomond's main tributaries (n = 8) recorded positive for presence of otters.



Comparison between this study and previous records indicated that there had been an increase in the proportion of tributaries with otters present from 0.5 to 1.0 between the late 1970s and 2002 (Fig. 2). Sprints and tracks of otters were seen at all four shore sites that were checked each month. The number of spraints found during each visit varied considerably. The greatest difference was seen at Ross Point with between 3 and 21 spraints found per visit in May and January 2002, respectively. In addition, mink (*Mustela vison*) scats were seen at all shore areas searched each month.

DISCUSSION

Distribution

This study was relatively limited in extent and restricted to the large tributaries and four main areas of shoreline of Loch Lomond. Nevertheless it provided useful base-line data for monitoring purposes. The area has a wide diversity of suitable habitats for otters ranging from the extensive shallow littoral zone of the loch itself to small lochans, rivers, streams and marshland. The diverse fish community provides a wide prey base to support the otter population. At least nine fish species and two amphibians have been recorded in otter spraints from Loch Lomond, with the introduced ruffe (*Gymnocephalus cernuus*) being the most frequently recorded species in the diet (McCafferty In press).

Population status

The increase in positive records of otters in Loch Lomond's tributaries since the late 1970s is in line with the increasing expansion of otter populations in Scotland as a whole, with otters now distributed over more than 90 % of available habitat (Green and Green 1997). The methods used in the previous National Otter Surveys involved searching a 600 m length of river at bridges. Although only 200 m was searched in this study, all sites had signs of otters and therefore the difference in methodology would not have biased the proportion of positive sites recorded.

The large area of loch Lomond could potentially support a sizeable otter population. However, the population size of an area such as Loch Lomond is unknown. A study by Green *et al.* (1984) of otters in the River Earn catchment (Perthshire) recorded 7 or 8 family groups on 98 km river with an average of 0.75 breeding females per 10 km of river. Erlinge (1967) in comparison recorded 3.6 – 5.6 otters per 10 km lakeshore in Southern Sweden. Loch Lomond has a shore length of approximately 80 km (not including islands) and an extensive river catchment providing suitable habitat for a relatively large population.

This study also found evidence of mink throughout the length of the loch. Mink are known to be widespread in the area (Mitchell 2001). Mink farms were previously established at Gartocharn, close to the southern end of the loch and at Fintry in the

River Endrick catchment where colonisation of the river was noted from 1964 onwards (Gibson 1984). There is overlap in the diet of otters and mink but mink generally take a greater proportion of aquatic birds and mammals (Jenkins and Harper 1980; Wise *et al.* 1981). In England otters are now recolonising river catchments where mink are present, whereas in Scotland mink became established during a period when otters were present. Competition between mink and otter in the Loch Lomond area is therefore unlikely to affect the status of the otter population. More important may be the interaction between humans and otters within the area. Otters have been recorded killed on the road near the Luss and Fruin Waters in recent years (R. Green unpublished data), giving concern that increased road traffic in the area may lead to an increase in mortality. Levels of hydrocarbons recorded within the surface waters of the loch have risen in the past 10 years with the increase in powerboat use for recreation (Bannan *et al.* 2001). Although it is not known the extent to which these may be incorporated into the aquatic ecosystem, its impact on top predators such as otters may be worthy of attention.

Future Monitoring

Studies have previously indicated that there is no simple relationship between the number of otter spraints and the abundance of otters in an area (Chanin 1985; Mason and Macdonald 1986). Sprainting behaviour appears to be dependent on a number of factors including age, social status, sex and season of the year and spraints are also washed away during periods of high water. Although spraints and tracks are unable to provide a reliable estimate of otter numbers, it is the simplest and least expensive method of monitoring at the present time. However, different approaches may be required to examine how the otter population may be affected by pollution or increased human activity.

ACKNOWLEDGEMENTS

Thanks to Colin Adams and all staff at the University Field Station Rowardennan for assistance throughout the project. Rosemary Green kindly provided unpublished records from previous otter surveys and gave valuable comments on an earlier draft of the manuscript. Forest Enterprise (Aberfoyle), Scottish Natural Heritage (Stirling), the Royal Society for the Protection of Birds, the Falloch Estate and Loch Lomond Golf Club kindly gave permission to access field sites. The work was funded by a grant from the Blodwen Lloyd-Binns Bequest (Glasgow Natural History Society).

REFERENCES

Adams, C.E. (1994). The fish community of Loch Lomond, Scotland: its history and rapidly changing status. *Hydrobiologia* 290, 91-102.

Bannan, M., Adams, C.E., & Pirie, D. (2001). Hydrocarbon emissions from boat engines: evidence of recreational boating impact on Loch Lomond. *Scottish Geographical Journal* 116, 245-256.

Chanin, P. (1985). The natural history of otters. Croom Helm Ltd, London.

Erlinge, S. (1967). Home range of the otter *Lutra lutra* L. in southern Sweden. *Oikos* 18, 186-209.

Gibson, J.A. (1984). The mammals of Dunbartonshire. *West Dunbartonshire Naturalist* 6, 11-34.

Gibson, J. A. & Mitchell, J. (1986). An atlas of Loch Lomond vertebrates. Clyde Area Branch Scottish Wildlife Trust.

Green, J., Green, R., & Jefferies,D.J. (1984). A radio-tracking survey of otters *Lutra lutra* on a Perthshire river system. *Lutra* 27, 85-145.

Green, R. & Green, J. (1997). Otter survey of Scotland 1991-1994. The Vincent Wildlife Trust.

Jenkins, D. & Harper, R.J. (1980). Ecology of otters in northern scotland II. Analysis of otter (*Lutra lutra.*) and mink (*Mustela vision*) faeces from Deeside, N.E. Scotland in 1977-78. *Journal of Zoology (London)* 49, 737-754.

Mason, C.F. & Macdonald, S.M. (1986). Otters: ecology and conservation. Cambridge University Press, Cambridge.

McCafferty, D. J. In Press. Importance of ruffe (*Gymnocephalus cernuus*) in the diet of otters (*Lutra lutra*) in Loch Lomond, Scotland. European Otter Conference: The return of the otter in Europe- Where and how? 30 June - 5 July 2003, Sabhal Mor Ostaig, Isle of Skye, Scotland.

Mitchell, J. (2001). Loch Lomondside. Harper Collins, London.

Wise, M.H., Linn, I.J., and Kennedy, C.R. (1981). A comparison of the feeding biology of Mink *Mustela vison* and otter *Lutra lutra*. *Journal of Zoology (London)* 195, 181-213.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 93-106.

THE EFFECT OF FINE DETRITAL MATERIAL AND MICROBIAL ACTIVITY ON THE PERMEABILITY OF INTERTIDAL SEDIMENTS FROM ARDMORE BAY, FIRTH OF CLYDE

Azra Meadows & Peter S. Meadows

Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, Scotland, U.K.

E-mail: gbza31@udcf.gla.ac.uk

ABSTRACT

Permeability is one of the major factors affecting benthic communities of animals, plants and microorganisms in marine and intertidal sediments such as those in the Firth of Clyde, Scotland. We have explored these relationships in experiments using natural and artificial sediments.

Two series of laboratory experiments have been conducted on the effects of detrital material and of photosynthetic and heterotrophic microorganisms on the permeability of natural intertidal sediments from Ardmore Bay, Firth of Clyde and of artificial sediment consisting of a pure quartz sand.

In the first experiment, fine detrital material (< 63µm) removed from natural marine sediment was added to natural and artificial sediments. In this experiment permeability's ranged from 0.27 to 0.064 $mm.s^{-1}$, and the addition of fines decreased permeability by 75% to 77%.

In the second experiment, microbial growth was stimulated over a period of 25 days by enrichment of naturally occurring marine photosynthetic and heterotrophic microorganisms under light and dark regimes. In this experiment permeabilities ranged from 0.25 to 0.49 x 10^{-4} $mm.s^{-1}$, and the microbial growth decreased permeabilities by 38% to 99.8%, over the 25 day period. Heterotrophic bacteria had the greatest effect in decreasing the permeability while diatoms and blue green algae were less effective.

Scanning electron microscopy was performed on sediments at the end of both experiments. Microbial activity and growth was measured at the end of the second experiment as follows. Primary productivity was measured by ^{14}C uptake, chlorophyll-a, phaeopigment and bacteriochlorophyll-ab by spectrophotometry, percent total organic matter (TOM) by loss of weight on ignition at 480°C, and heterotrophic bacteria by viable bacterial counts expressed as colony-forming units. The most significant differences were very high primary productivity and chlorophylls in the sediments incubated in the light, and high TOM and heterotrophic counts in the sediments incubated in the dark.

The results are discussed in relation to the permeability of sediments in high and low energy coastal environments such as those in the Firth of Clyde, and in relation to the mechanisms involved in the clogging of pore spaces which lead to reduced permeability. It is concluded that fine detrital material and microbial growth will significantly reduce the permeability of sediments in low energy coastal environments. This reduction in permeability will have major effects on the redox conditions in surficial sediments - thus influencing the nature of macrobenthic communities of infaunal invertebrates. At a later stage it will have a significant influence on diagenetic processes in the sedimentary column. The mechanisms causing reduced permeability consist of microbial cells physically obstructing the pore spaces and of microbial extracellular polymeric secretions that clog pore throats.

INTRODUCTION

The superficial layers of coastal marine and estuarine sediments within 1 to 2m of the sediment/water interface represent a complex system whose characteristics are determined by the input and output of sedimentary materials, and by biological activity and chemical changes in the sediment and overlying water (Newell, 1965; Fenchel & Riedl, 1970; Duinker *et al.,* 1974; Belyaev & Laurinavichus, 1978; Lein, 1978; Lyons & Fitzgerald, 1978; Bauld, 1981; Aller, 1982; Folsom & Wood, 1986; Meadows, 1986; Meadows & Tufail, 1986; Sanchez de Lozada *et al.*, 1994; Richardson *et al.,* 2002). Sediment permeability is one of the major factors that plays an important role in controlling these processes. A large number of physical features are known to affect permeability including particle size and shape, packing, porosity and temperature (Fraser, 1935; ASTM, 1967; Webb, 1969; Beard & Weyl, 1973; Lambe & Whitman, 1979; Palmer & Barton, 1987; Rusch & Huettel, 2000). Biological factors also play a significant role. Calculations by Weaver and Schultheiss (1983) suggest that burrows produced by infaunal invertebrates in deep sea sediments are likely to have a major impact on permeability, and Meadows and Tait (1989) have demonstrated in laboratory experiments that the burrowing crustacean *Corophium volutator* and a polychaete *Hediste diversicolor* collected from the Firth of Clyde, significantly alter the permeability of inshore sediments.

Changes in permeability of sediments induced by microbial activity have also been documented and can have considerable applied importance. For example at a microbial level, the clogging of pores is a significant factor in water quality, waste water treatment, and

aquifer recharge (Takai *et al.*, 1956; Ripley & Saleem, 1973; Okubo & Matsumoto, 1983; Hilton & Whitehall, 1979; Kristiansen, 1981; Oberdorfer & Peterson, 1985; Lee *et al.*, 1988; Taylor & Jaffé, 1990; Taylor *et al.*, 1990; Huettel *et al.*, 2003).

In contrast, less is known of the effects of marine microbial populations and associated detrital material on the permeability of sediments in marine coastal zone and estuarine sedimentary ecosystems (Krumbein, 1983; Cornée *et al.*, 1992; Vandevivere & Baveye, 1992a, b; Sanchez de Lozada *et al.*, 1994; Rasheed *et al.*, 2003, 2004).

With this background, the aims of the present investigation have been to conduct experiments that consider the importance of natural detrital material and microbial activity in the context of coastal marine sedimentary ecosystems, with particular reference to the estuarine ecosystem. We have studied the degree to which the permeability of sandy sediments collected from Ardmore Bay may be altered, firstly by fine detrital material consisting of natural microbial communities, organic and inorganic material, and secondly by enhanced levels of microbial communities. Two laboratory experimental approaches have been adopted. The first involved testing the effect on permeability of removing natural fine detrital material from intertidal sediment obtained from Ardmore Bay, Firth of Clyde, and then adding it to natural and commercial sediments. The second involved testing the effects on sediment permeability of enriching natural sediment from Ardmore Bay, Firth of Clyde with media that would stimulate the growth of photosynthetic microbial communities (diatoms and blue-green algae) and of heterotrophic microbial communities (bacteria) - under light and dark conditions.

Our results are directly relevant to sediments and their biological communities in the Firth of Clyde area, and also have wider implications for coastal ecosystems generally.

MATERIALS AND METHODS

Natural muddy sand sediment was collected at low tide level from Ardmore Bay, Firth of Clyde, Scotland (Nat. Grid. NS 320 792). This is referred to as natural sediment from here on. A commercially available pure quartz sand (supplied by Rockware Ltd., Irvine, Ayr) was also used. This is referred to as Rockware sand from here on. Samples of natural sediment and Rockware sand were analysed for particle size by dry sieving (BS 1377, 1975; Buchanan, 1984) and the mean particle size was calculated. The mean particle sizes of the natural sediment and the Rockware sediment were 195.2 μm and 237.5 μm respectively.

Two laboratory experiments were conducted. For both experiments 29mm diameter 500mm long cores were prepared as follows. The lower end of each core was covered with a stainless steel mesh (80 squares per inch) below which was stretched a fine nylon mesh. The steel and nylon meshes were retained by a plastic clip around the base of the core. This arrangement allowed free flow of water but retained sediment and detrital material

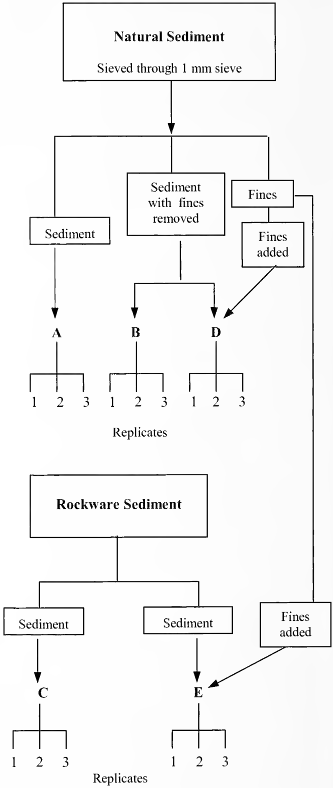


Figure 1. Experiment 1. Flow diagram showing the preparation of the five sediment treatments. (A) natural sediment; (B) natural sediment with fines removed; (C) Rockware sand; (D) natural sediment from which fines had been removed and then added again; (E) Rockware sand with fines added.

Experiment 1

The following five sediment treatments were tested; natural sediment (A), natural sediment with fines removed (B), Rockware sand (C), natural sediment from which fines had been removed and then added again (D) and Rockware sand with fines added (E). The fines consisted of interstitial detrital material and microorganisms.

Preparation of sediment cores

The sediment was firstly sieved through a 1 mm sieve to remove macrofauna. Fines (< 63 µm) were then removed from the sediment as follows. 1000ml of natural sediment was mixed with 300ml of filtered seawater. This was left to settle for 30 sec. After which the supernatant was carefully decanted. This procedure was repeated 18 times until the supernatant was clear. The supernatant was then decanted and the remaining volume containing the fines was made up to 1000ml with 0.45µm membrane filtered seawater.

The fine material in the combined rinses was concentrated by settling for 24 hours. The sediment cores were packed by pouring slurried sediment gently through membrane filtered seawater to give a 50mm sediment bed height, and 200mm water level above the sediment surfaee. The general procedure for preparing the sediment treatments (A) to (E) is shown in figure 1.

After a 24h period four readings of permeability were taken on each of the cores by measuring the time taken for the water to fall 25mm. The water level was then topped up to the 200mm mark with the appropriate solution and three more permeability readings were taken. Permeability coefficients k ($mm.s^{-1}$) were calculated using the following equation (Smith, 1981)

$$k = (l/t). \ln(H1/H2)$$

where l is the height (mm) of sediment in the core, t is the time in seconds for the water level to fall from height H1 (250mm) to height H2 (225mm).

Experiment 2

Ten glass columns were prepared as previously and autoclaved.

Photosynthetic, bacterial and control media

The photosynthetic medium was a modification of Medium M12 (Asher & Spalding, 1982) and contained 50ml soil extract, 2g $NaNO_3$ and 0.014g $Na_2HPO_4.2H_2O$ made up to 1 litre with artificial seawater. The bacterial medium contained 5g bacteriological peptone (Oxoid L37) (Cruickshank et al., 1975) and 0.1g $FePO_4$ made up to 1 litre with artificial seawater. The control medium contained 25ml of 40% formaldehyde completed to 70ml with distilled water and made up to 1 litre with 82% artificial seawater. The final salinity of the seawater in all media was 26‰. This salinity was equivalent to the average salinity in Ardmore Bay where the natural sediment was collected. Media were autoclaved and filtered through sterile Whatman No. 1 filter paper before use.

Preparation of sediment cores and conduct of the experiment

Natural sediment sieved through a 500µm sieve with 0.45µm membrane filtered seawater was used for preparing sediment cores. The sediment cores were prepared as in experiment 1 using the appropriate media with a 50mm bed height and a media height of 450mm above the sediment surface. The level of the liquid was allowed to fall from the top of the glass core at 500mm to 100mm above the bottom of the core taking the successive times for each vertical interval of 25mm which provided 17 successive time intervals and hence 16 permeability readings using the equation above. The mean of these 16 permeability readings constituted the permeability of the core.

Four of the cores were filled with photosynthetic medium M12 (M) to stimulate photosynthetic growth, four with bacterial medium (B) to stimulate bacterial growth, and two with formalin (C) to inhibit microbial growth. The ten cores containing sediment were maintained at 18°C.

Two of the photosynthetic medium cores and two of the bacterial medium cores were maintained in a 17h light / 7h dark photoperiod (L), and the remaining two from each medium were maintained in the dark (D). The control formalin cores were left in the light. The experiment was run for 25 days and every third day the medium was changed and 16 permeability readings taken as before.

Measurement of microbial parameters

At the end of the 25 day experiment sediment was removed from each core into a sterile container and mixed with a sterile spatula. This sediment was divided into suitable portions for measurements on primary production by ^{14}C uptake method (Steeman Nielsen, 1952; Unesco, 1966; Strickland & Parsons, 1972; Unesco, 1973; Parsons *et al.,* 1984) and on chlorophyll-a, phaeopigment and bacteriochlorophyll-ab by spectrophotometric method (Takahashi & Ichimura, 1968; Strickland & Parsons, 1972). Percent total organic matter (TOM) was determined by loss of weight on ignition at 480°C (Byers *et al.,* 1978). Standard plating techniques were used to estimate viable bacterial counts as colony-forming units (Cruickshank *et al.,* 1975).

Scanning electron microscopy

Scanning electron microscopy was done on samples from both experiments. Samples of fines (collected on a 0.22µm membrane filter), and sediment enriched with photosynthetic and bacterial media were fixed in 2.5% glutaraldehyde in membrane filtered seawater. After one week the samples were rinsed with membrane filtered seawater and transferred to sodium cacodylate buffer pH 7.6 and then fixed in 2% Osmium tetroxide for 1h. This was followed by

dehydration in an ascending series of acetone and critical point drying from anhydrous analar acetone. Samples were mounted on aluminium stubs using 'Quick-Dry' colloidal silver paint and gold coated to a thickness of 20nm and examined under an SEM.

RESULTS

Experiment 1

The results of the first experiment are shown in figure 2. There were clear differences in the permeability shown by the five treatments. Treatment B, natural sediment with fines removed, and treatment C, Rockware sand which contained no fines, had high permeabilities. Treatments A, D and E which consisted of natural sediment containing fines, natural sediment from which fines had been removed and then re-added, and Rockware sand to which fines had been added had low permeabilities.

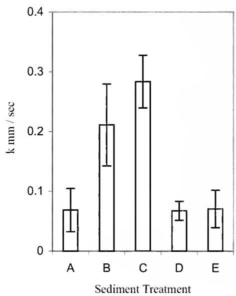


Figure 2. Experiment 1. Permeability coefficient k ($mm.s^{-1}$) for the five sediment treatments A, B, C, D and E. The mean (column) and standard deviation (bar) of the 4 permeability runs on the 3 replicate cores for the treatment (n=12).

The statistical analysis entirely substantiated these results and consisted of a two-way analysis of variance on the permeabilities obtained from the four successive runs from each of the three replicate cores in each treatment. The two-way analysis of variance (Table 1) showed that the differences between the treatments were highly significant (Factor A). There were also significant differences between successive runs (Factor B). Inspection of the original data showed that this latter effect was caused by the permeability progressively decreasing between runs 1 to 4 in all treatments. This is probably caused by progressive packing, and it occurs whether the fines are present or absent.

The results of the experiment show, therefore, that fines play a central role in reducing the permeability of both natural and Rockware sediments. This is further emphasised by the following points. Firstly, there is a lack of difference between the permeabilities of A, D and E. This is interesting because the removal of fines from natural sediment and then addition again to it, (treatment D), produces a sediment whose permeability is the same as natural sediment containing fines that have not been removed (treatment A). Secondly, addition of fines to a different sediment which did not contain fines, in other words the Rockware sand (treatment E), produced a sediment of low permeability statistically not different from that of the natural sediment (treatment A) from which the fines had been originally obtained.

The nature of the fine material is complex, consisting of organic and inorganic detritus and a diverse assemblage of microbial cells such as bacteria, diatoms and blue-green algae. Figure 3a and 3c shows representative detrital material. Intact and broken diatom cells can clearly be seen amongst the detrital material in 3a, while a distinctive network of fibres is visible in 3c. These constituents of the detrital material will provide a highly effective packing between individual sand grains in the sediment fabric which will reduce the sediment permeability.

Experiment 2

The second experiment was designed to boost the microbial populations that occur in the fine material in the interstices of the sediment and that are attached to sediment particles under natural conditions (Meadows & Anderson, 1968; Anderson & Meadows, 1978; Tufail, 1985).

The results of the experiment, which was run for 25 days are shown in figure 4. All four enrichment regimes caused a highly significant reduction in the permeability of the sediments when compared with the control, and these effects were noticeable from the early stages of the experiment. This means that enhanced microbial growth has a rapid effect in reducing the permeability of sediments that can be detected within a few days. The non-significant reduction in the permeability of the control cores is attributed to sediment packing noted previously.

The results of the five enrichment regimes on day 25 were analysed statistically by comparing pairs of media in turn by 1x2 one-way analyses of variance. A summary of the results of these one-way analyses of variance are given in Table 2 and show that all the enrichment columns had significantly lower permeabilities than the control columns and that all four enrichment treatments were statistically different from each other.

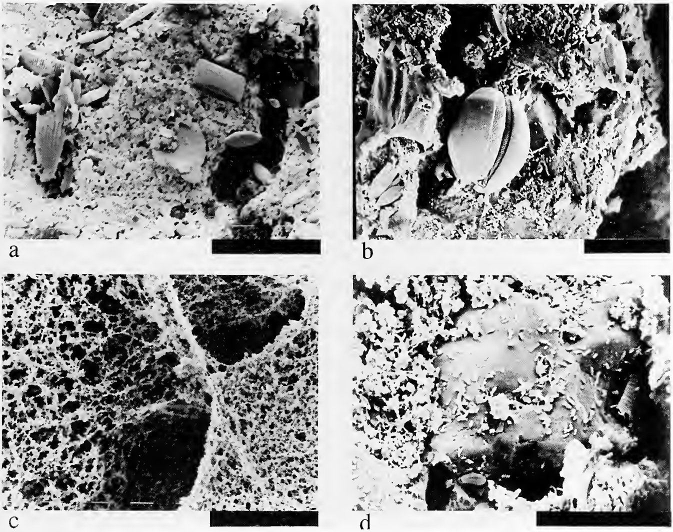


Figure 3. Scanning Electron Microscope photomicrograhs. (a) Detritus and diatom frustules in the fines. Experiment 1. (b) Diatoms and bacteria on a sand grain in ML core. Experiment 2. (c) Network of fibres in the fines. Experiment 1. (d) Bacteria scattered on a sand grain surface and detrital material in interstices of the sediment (on left hand side) in BL core. Experiment 2. (a), (b), (c) and (d): Scale bar 50μm.

Table 1. Experiment 1. Two-way analysis of variance of permeability ($mm.s^{-1}$) testing differences between sediment treatments A, B, C, D, and E (Factor A) and runs 1 to 4 in the cores (Factor B). There were three replicate readings per cell in the analysis, one from each of the three replicate cores.

Factor A: Treatments
Sum of Squares (SS): 0.4896
Mean Square (SS/DF): 0.1224
Degrees of Freedom (DF): 4
F Ratio: 81. 59
Probability: P<0.001***

Factor B: Runs
Sum of Squares (SS): 0.02847
Mean Square (SS/DF): 0.00949
Degrees of Freedom (DF): 3
F Ratio: 6.327
Probability: 0.005>P>0.001**

AxB Interaction
Sum of Squares (SS): 0.01271
Mean Square (SS/DF): 0.00106
Degrees of Freedom (DF): 12
F Ratio: 0.7067
Probability: 0.75>P>0.5

Residual: Error
Sum of Squares (SS): 0.05986
Mean Square (SS/DF): 0.00150
Degrees of Freedom (DF): 40

Total
Sum of Squares (SS): 0.5906
Degrees of Freedom (DF): 59

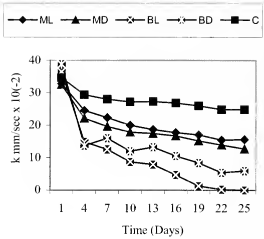


Figure 4. Experiment 2. Mean permeability coefficient k ($mm.s^{-1}$) x 10^{-2} of the 2 replicate cores for ML, MD, BL, BD and C for days 1 to 25. M - photosynthetic medium; B - bacterial medium; L - light; D - dark; C - control.

The greatest reduction in permeability occurred in the cores enriched with bacterial medium with a lesser effect being shown by cores enriched with photosynthetic medium.

Table 2. Experiment 2. Comparisons of differences in permeability ($mm.s^{-1}$) between pairs of media on day 25. Probabilities are 0.05>P>0.01*, 0.01>P>0.001**, P<0.001***. F-ratios from 1x2 one-way analyses of variance comparing treatments in turn. 16 replicate readings per cell

Media	MD	BL	BD	C
ML	73.42***	1006***	1006***	507.9***
MD		1264***	31.35**	1109***
BL			7.75**	2040***
BD				238.7***

Scanning electron microscopy of sedimentary material sampled from the enriched columns at the end of the experiment provides a qualitative picture of the microbial communities that developed in the columns. Large numbers of diatoms and blue-green algae were observed in the sediments enriched with photosynthetic medium, particularly those maintained in the light (Fig. 3b), and very large numbers of bacteria were seen in the sediments enriched with bacterial medium. Figure 3b shows diatoms of various sizes and bacteria in a sample taken from the sediment enriched with photosynthetic medium and incubated in the light and figure 3d shows bacteria scattered on the surface of a sand grain with bacteria and detrital material in the interstices of the sediment on the left hand side of the photomicrograph.

The microbial and chemical measurements taken on the cores at the end of the experiment quantify the differences in microbial communities produced by the different enrichment regimes (Table 3). As expected, the highest levels of overall photosynthetic microbial activity by diatoms and blue-green algae measured by ^{14}C fixation, occurred in the cores enriched with photosynthetic medium and maintained in the light (1.851 mg C fixed. g^{-1} h^{-1}). There was however a significant carbon fixation in the cores enriched with photosynthetic medium and maintained in the dark (0.5769 mg C fixed. g^{-1} h^{-1}). This probably reflects photosynthetic microorganisms which have remained dormant but viable during the experiment, that are stimulated to photosynthesise when exposed to light during the ^{14}C technique at the end of the experiment. Counts of viable heterotrophic bacteria (colony forming units - CFU's) showed that all four enrichment treatments contained significant numbers of bacteria but that the cores enriched with bacterial medium contained much larger numbers than the cores enriched with photosynthetic medium (885 and 715 x 10^6 CFU. g^{-1} compared with 11.4 and 10.5 x 10^6 CFU. g^{-1} respectively).

Table 3. Experiment 2. Rate of primary production (PrPr. ($mgC.g^{-1}.h^{-1}$), and amount of chlorophyll-a (Chl a ($\mu g.\ g^{-1}$)), bacteriochlorophyll-ab (BChab ($\mu g.\ g^{-1}$)), phaeopigment (Phaeo ($\mu g.\ g^{-1}$)), percent total organic matter (TOM), and colony forming units (CFU (x $10^6.g^{-1}$)) in the five media sediment on day 25. Figures represent means $\pm$ standard deviations.

ML	MD	BL	BD	C
PrPr				
1.851	0.5769	0.0823	0.0382	0
±1.136	±0.0841	±0.0978	±0.0540	
Chl a				
7.388	5.253	3.003	4.462	2.699
±2.659	±0.2297	±1.082	±0.3306	±0.142
BCh-ab				
0.4624	0.1191	6.211	0	0.2259
±0.1477	±0.1684	±4.079		±0.0112
Phaeo				
2.160	1.795	0	1.419	1.903
±0.2347	±0.7185		±0.4780	±1.058
%TOM				
0.5712	0.5400	0.8479	0.8100	0.5451
±0.0122	±0.0129	±0.0330	±0.0337	±0.0097
CFU				
11.4	10.5	885	715	0
±1.259	±0.9893	±3.780	±3.860	

The chlorophyll measurements are interesting. Chlorophyll-a levels, which are an estimate of the number of eukaryotic photosynthetic microorganisms such as diatoms, were highest in the cores enriched with photosynthetic medium and maintained in the light (7.388 µg chlorophyll-a g^{-1}). Bacteriochlorophyll-ab levels, which are an estimate of the number of prokaryotic photosynthetic microorganisms such as purple sulphur bacteria, were highest in the cores enriched with bacterial medium and maintained in the light (6.211 µg bacteriochlorophyll-ab. g^{-1}) These results are to be expected in view of the two media used.
The percent total organic matter (TOM) was higher in the cores enriched with bacterial medium than in the cores enriched with photosynthetic medium (0.8479 and 0.8100 % TOM compared with 0.5712 and 0.5400 % TOM). We interpret this as being due to the much greater bacterial cell numbers (CFU's) in these sediments, combined with a significant quantity of extracellular polymeric material which bacteria secrete under these conditions.
Overall, the results of the second experiment demonstrate clearly that microbial communities in sediments can have a highly significant effect in reducing permeability. In our experiments the most important microorganisms reducing permeability are the heterotrophic bacteria that developed in the cores enriched with bacterial medium rather than the larger photosynthetic microorganisms such as the diatoms that developed in the cores enriched with photosynthetic medium and maintained in the light.

Comparison of Experiment 1 and 2

A comparison of the results of experiment 1 and 2 is interesting. In experiment 1, detrital material was removed from sediment and then returned to it, and the permeability of the sediment was thus reduced. In experiment 2, natural microbial populations present on the sand grains (Meadows & Anderson, 1968) were enriched to increase their abundance, and as a result the permeability of the sediment was reduced. It is not possible to make an exact comparison between the two experiments because their experimental protocols were different. However there are clear similarities when the percentage reductions in permeabilities are compared (Table 4). These percentages were all calculated in relation to the control cores (C) in order to make the comparisons more clear.
In experiment 1, the permeability of the natural sediment with fines removed (treatment B) and of the Rockware sand which contained no fines (treatment C) were 0.22 and 0.27 $mm.s^{-1}$ respectively. The permeabilities of natural sediment containing fines (treatment A) or to which fines had been returned (treatment D), and of Rockware sand to which fines had been added (treatment E), were all within the range 0.064 to 0.067 $mm.s^{-1}$. Based on a 100% value of 0.27 $mm.s^{-1}$ (treatment C), these latter values are in the range of 23% to 25%. In other words adding detrital material reduces the permeability of the two sediments used by between 75% and 77%.
In experiment 2 at the end of experiment on day 25, the permeability of the cores enriched with photosynthetic medium were 0.155 $mm.s^{-1}$ (ML) and 0.125 $mm.s^{-1}$ (MD) respectively, and those of the cores enriched with the bacterial medium were 0.49 x 10^{-4} $mm.s^{-1}$ (BL) and 0.066 $mm.s^{-1}$ (BD) respectively. The permeability of the control core (C) was 0.25 $mm.s^{-1}$. Based on a 100% value of 0.25 $mm.s^{-1}$, the percentage permeability of the enriched cores were 62% (ML), 50% (MD), 0.2% (BL) and 26% (BD) (Table 4). In other words the percentage reductions in permeability induced by the growth of the microorganisms in the enriched cores were 38% (ML), 50% (MD), 99.8% (BL) and 74% (BD).
The 100% value in experiment 1 of 0.27 $mm.s^{-1}$ - the permeability of Rockware sand without fines, and the 100% value in experiment 2 of 0.25 $mm.s^{-1}$ - the permeability of the control cores, are very similar. This means that fairly direct comparisons of the percentages can be made between the permeabilities obtained in the two experiments. Firstly, sediment without fines (treatments B and C) in experiment 1

Table 4. Percentage reductions in mean permeabilities in experiment 1 and experiment 2. See Fig. 1 and Fig. 4 legends for treatments (A, B, C, D, E) and media (ML, MD, BL, BD, C) notations. Percentages were all calculated in relation to the control cores (C).

Experiment 1. (Mean permeability)

% of Greatest Mean Permeability

A	**B**	**C**	**D**	**E**
24	74	100	23	25

% Reduction in Permeability

A	**B**	**C**	**D**	**E**
76	26	0	77	75

Experiment 2. (Final Permeability)

% Greatest Final Mean Permeability

ML	**MD**	**BL**	**BD**	**C**
62	50	0.2	26	100

% Reduction in Permeability

ML	**MD**	**BL**	**BD**	**C**
38	50	99.8	74	0

are closely equivalent in terms of their permeabilities to the control sediment (C) in experiment 2. Secondly, the reductions in permeability produced by the addition of fines in experiment 1 fall within the range

of the reductions in permeabilities produced by the growth of microbial communities in the enriched sediment columns in experiment 2. Lastly, the columns in experiment 2 - which were enriched with bacterial medium and maintained in the dark (BD) had a 74% reduction in permeability, which is directly comparable with those produced by the addition of detrital material (D 77% and E 75%) and the natural sediment containing fines (A 76%) in experiment 1.

DISCUSSION

Our discussion is divided into three parts. The first discusses the significance of our results for the natural environment. The second considers the mechanisms that may lead to the reduction of sediment permeability observed in the current experiments. The third takes a broader ecological view of the causes and effects of changes in sediment permeability in exposed and sheltered intertidal environments such as those in the Firth of Clyde.

Significance of the results to natural environments

The experiments reported in this paper were designed to test whether fine detrital material and microbial communities decrease the permeability of sediments in coastal marine sedimentary ecosystems. The marine sediments we used, together with the detrital material and microorganisms in them, are typical of moderate energy nearshore coastal zone environments, although when the fines have been removed (B) the sediment may represent a high energy environment, as well as the Rockware sand without any fines (C). Our experiments therefore have a direct applicability to sediments from these environments.

The results of the first experiment in which fine detrital material in the sediments is shown to have a highly significant effect in reducing sediment permeability, has important implications for the development and maintenance of coastal zone sedimentary environments in exposed high-energy and sheltered low-energy environments. In high energy environments that occur on exposed sandy shores or in some subtidal areas like those in the English Channel, wave action and water currents do not allow the sedimentation of detrital material and also winnow out any that is present in the surficial sedimentary layers. Sediment permeability in these environments will therefore be high (Fig. 2. treatments B and C) and aerobic conditions will persist in the top 15-20cm of the sediment . This will have important effects on the nature of the macrofaunal and microbial communities that will develop in the top half metre of the sedimentary column and hence on the resultant biogeochemical changes that take place deeper in the column.

In low energy environments on the other hand, wave action and water currents are much reduced. This occurs in sheltered areas such as shallow-water coastal bays and in parts of the Firth of Clyde, Scotland. In these environments, large quantities of detrital material are likely to be deposited at the sediment water interface and then become progressively incorporated into the sedimentary column (Fig. 2. treatments A, D, and E). Sediment permeability in these environments will be low and anaerobic conditions will occur usually continuously in the sedimentary column. Very different macrofaunal and microbial communities develop in these circumstances, with characteristically different effects on the subsequent biogeochemical history of the sediment during diagenesis. Anaerobic conditions will develop closer to the sediment water interface - reaching it in extreme conditions, and typically anaerobic microbial communities including sulphate reducing bacteria will be common.

The results of the second experiment in which microbial communities were enriched also have important implications in coastal sedimentary environments. The two types of enrichment media used in the experiment combined with the light and dark regimes, mimic environmental conditions occurring in a range of near shore, continental shelf and greater depths in ocean environments. The greatest reduction in permeability took place in the cores enriched with the bacterial media (BL, BD). These mimic sediments with relatively high organic content both within the photic zone and below it in deeper waters. In inshore waters the photic zone, where net photosynthesis can occur, often extends to only 10 metres water depth in muddy waters, and not so in many seas. These conditions are common in a number of near shore shelf sediments and are well known for example in the Clyde Sea area, Scotland, and the Irish Sea between Britain and Eire (Halcrow et al., 1973; Pearson et al., 1986). The sediments enriched with photosynthetic medium mimic intertidal and near shore sediments showed less of a reduction in permeability so one may deduce that microbial growth under these conditions in the field will have less of an effect.

The reduction in permeability produced by fine material and by microbial communities must be produced by clogging mechanisms which slow the flow of water through the pore spaces and this reduction in permeability will have major implications for the geochemistry of the sediment and the early stages of diagenesis in near shore sedimentary ecosystems. For example a reduction of permeability produced either by fine suspended material being incorporated into the sedimentary column or by *in situ* growth of microorganisms and the resultant breakdown of organic matter is likely to lead to a reduction in the redox potential in localised areas where the permeability and liquid flow decreased. The reduction in redox potential itself will lead to changing microbial communities. Aerobic

heterotrophic microorganisms will die out and the anaerobic ones like the sulphate reducers will increase (Jørgensen & Fenchel, 1974; Jørgensen, 1977; Ivanov, 1978).

Mechanisms of reduction in sediment permeability

The mechanism by which the fines block the flow channels within the sediment is likely to be a physical blockage phenomenon in which the fine material becomes lodged in the interstices which will in turn lead to further blockage. Bodman (1937) and Fireman and Bodman (1939) have commented on the blocking of liquid flow in terrestrial soils and suggest that as the liquid flows downwards through a soil it causes dispersion and rearrangement of fine clay particles which then block the pores and reduce permeability. Our detrital material may act in a similar manner, although it's constituents are larger than typical clay particles. Clay particles are significantly less than one micron in size, while detrital material ranges from one micron upwards – to visually recognisable particles and flocs. In a related context we have observed fine green detrital material on the surface of sediment samples collected from the Oxygen Minimum Zone in the Arabian Sea during the post-monsoon period between water depths of 500 to 1000m (Meadows *et al.* 2000). This material is mainly a result of the fallout of phytoplankton from surface waters as phyto-detritus.

The way in which microbial communities reduce the permeability of sediment is likely to be more complicated. It is certainly true that larger microorganisms such as the diatoms (particularly those which form chains of cells) will block water flow by a purely physical mechanism within the sediment. However many groups of microorganisms living in sediments are known to produce extracellular polymeric materials such as mucopolysaccharides that are likely to act as glues or binding materials (Allison, 1947; McCalla, 1950; Gupta & Swartzendruber, 1962; Nevo & Mitchell, 1967; Hobbie & Lee, 1980; Vandevivere & Baveye, 1992a, b; Murray *et al.* 2002). It is not known how significant the effects of these polymeric materials are in our columns but their production must inevitably reduce the flow of water by reducing the pathways for free-flow.

For example Mitchell and Nevo (1964) in an experiment on beach-dune sand added the protein casein together with sulphur and iron to stimulate microbial growth. They percolated tap water (fresh water) through the columns and measured changes in permeability over an eight day period. At the end of the experiment they measured extracellular polymeric material produced by the freshwater bacteria in their columns and showed a clear relationship between reduced permeability and the amount of extracellular polymeric material produced. From their data they suggest that 90% of the clogging is caused by extracellular polymeric material and only 10% by the bacterial cells themselves. Shaw et al. (1985) have also shown that the permeability of sintered glass bead cores decreased significantly by 99% due to the production of exopolysaccharide by bacteria. If similar percentages apply in our columns and more generally in marine sediments of high organic content, it suggests that extracellular materials produced by bacteria and other microorganisms are likely to play a central role in determining the permeability of these sediments and hence their redox balance and detailed geochemistry.

Other mechanisms may be at play. These may involve complex three dimensional interactions between the sediment fabric and the growing microbial colonies which may change depending on the position of the colonies in the sedimentary column. Vandevivere and Baveye (1992a) have demonstrated effects of this sort. Their laboratory experiments show that the bacterium *Arthrobacter sp.* does not form a uniform film around sand grain surfaces (c.f. Meadows & Anderson, 1968) but forms three-dimensional aggregates in the pores of quartz sand which significantly reduce the permeability. The bacterium forms an orange mat at the inlet boundary of the sand columns, and if colonisation is prevented at this site then clogging of pores continues in the bulk of the sand but at a slower rate. We observed similar effects in our experiments as distinct biofilms on the surface of the photosynthetic and bacterial cores. The development of biofilms such as these may prevent solute and gas transfer between sediment and the overlying water column therefore increasing the reducing conditions in the sediment below (Cornée *et al.,* 1992), and similar conditions may have occurred in our light and dark bacterial cores.

The broader ecological framework

Our results can also be viewed within the broader ecological framework of intertidal environments. This firstly concerns the close relationship between the abundance and activities of sedimentary organisms and the properties of sediments. Secondly, our results are directly relevant to differences between high-energy and low energy sedimentary environments that are .

Firstly consider the relationship between sedimentary organisms - the benthos - and sediment properties (Fig. 5). The defend categories of organisms in sediments, ranging from the smallest microorganisms to the largest infaunal invertebrates, will by their presence and activities affect the chemical and physical properties of sediments. The results in the present paper demonstrate this very clearly. Promotion of the growth and activities of autotrophic and heterotrophic microorganisms reduces the sediment permeability. A similar effect is achieved by

the addition of detrital material. Both effects must operate through a reduction of pore space in one way or another – see above. These effects are asterisked in figure 5. The occurrence of detrital material in sediments is of interest in itself, as it can be formed by the activities and breakdown products of each of the biological groups of organisms listed in the upper part of figure 5. There will also be a utilisation of detrital material that has become entrapped at or just below the sediment surface - by bacterial metabolism and by invertebrate infaunal feeding. So the nature of the detrital material, and its interactions with biological activity and sediment properties is complex and deserves more attention, both from an experimental and a field perspective. These points are of particular

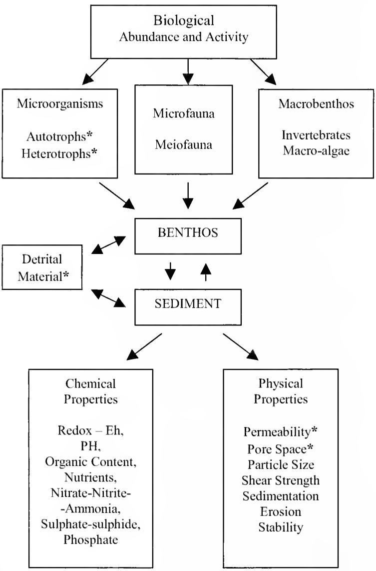


Figure 5. Benthic faunal abundance and activity, and its relation to sediment chemical and physical properties (Meadows & Tufail, 1986). Asterisks denote items that have been investigated in the present paper or are of direct relevance to results in the current paper.*

interest in relation to sediments at Ardmore Bay as detritus is regularly seen accumulating in the troughs of sediment ripples in the intertidal zone there. Furthermore this material is often recognisably macroalgal and also terrestrial, together with casts of the very abundant mud shrimp – *Corophium volutator*. It is a fascinating phenomenon.

Secondly, our results are of direct to the very obvious differences between high-energy exposed intertidal environments and low energy sheltered intertidal environments (Fig. 6). Sheltered intertidal beaches are usually only exposed to weak wind action, which leads to weak waves and currents. These environments have sediments that consist of fine sand, muddy sand or mud, and may well contribute to the development of salt marshes. Exposed intertidal beaches are often exposed to strong winds, which leads to strong waves and currents. These environments have sediments that consist of gravel or coarse sand. Both types of environment are found in the region of Ardmore Point and Ardmore Bay. The former is a rocky and exposed intertidal environment and the latter is sheltered and has salt marsh at its landward fringe.

Low Energy Environments	**High Energy Environments**
Sheltered Intertidal Beaches	Exposed Intertidal Beaches
Weak Wind Action	Strong Wind Action
Weak Waves and Currents	Strong Waves and Currents
Sediments: Fine Sand, Muddy-sand, Mud	**Sediments:** Gravel, Coarse Sand

Figure 6. The differences between low energy and high energy intertidal environments.

The sequence of events starts conceptually with high wind action and strong waves and currents for an exposed intertidal environment, and the reverse for a sheltered intertidal environment (fig. 7). In the exposed intertidal environment fine material is removed by the strong wave and current action. This erodes some of the finer material consisting of fine sand, mud and detritus. The result of this removal is that the interstices between the sediment particles are increased in size and sediment permeability is high. The reverse is true in sheltered intertidal environments, leading to low sediment permeability. Here, detrital organic material accumulates at the

sediment surface and becomes incorporated into the sedimentary column. It is derived from a number of aquatic and terrestrial sources, including microbial cells, leaf litter, and breakdown products of seaweeds and dead invertebrates.

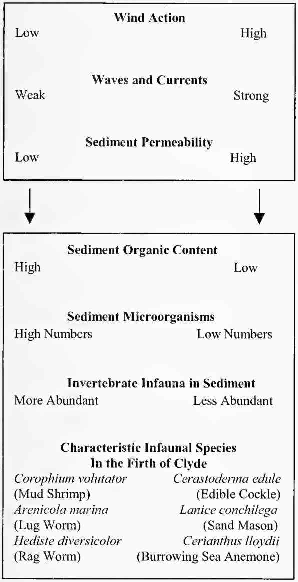


Figure 7. Relationships between wind action, waves and currents, sediment permeability, organic content, abundance of microorganisms, and invertebrate infauna. Characteristic infaunal species in the Firth of Clyde are also given.

Low permeability sediments usually have a high organic content, and so the abundance of microorganisms that feed on this organic material increases. These sediments may then become anaerobic because when the microbial abundance increases more oxygen is used. This eventually leads to sediments that smell of hydrogen sulphide (with negative redox values) below the sediment surface. The microbial community also changes – anaerobic forms such as *Desulfovibrio desulfuricans* replace aerobic bacteria. Higher levels of organic material and higher microbial abundance leads to a higher abundance of burrowing invertebrate infauna because the increase in organic matter and microorganisms provides these invertebrates with an increased food source. As with the microorganisms, the types of invertebrate species in sediments that tend towards anaerobic conditions also change. Here, species such as the mud shrimp Corophium volutator and the rag worm *Hediste (Nereis) diversicolor*, and the lug worm *Arenicola marina* are common. In contrast, in coarser sediments from higher energy intertidal environments – with their high permeability, low organic content and low microbial abundance, different species of invertebrate infauna are common. These species include the edible cockle *Cerastoderma edule*, the sand mason *Lanice concheliga*, and the burrowing coelenterate *Ceriantlms lloydii*.

CONCLUSIONS

The laboratory experiments conducted in this study demonstrate that fine detrital material and photosynthetic and heterotrophic microorganisms significantly reduce the permeability of marine intertidal sediments. These results are directly relevant to sedimentary environments in the Firth of Clyde and have important implications for the invertebrate fauna that live in these sediments.

In the first set of experiments the presence of fines in natural sediment and fines added to clean sediment resulted in low values of permeability when compared with sediment without fines or sediment from which fines were removed. The fine detrital material which led to reduction in sediment permeability consisted of organic and inorganic detritus and a range of microbial assemblages such as bacteria, diatoms and blue green algae. These conditions can occur in areas of storms and turbidity currents where internal waves cause resuspension of fine material from the top few centimetres of surface sediment which is suspended and removed in the nepheloid layer resulting in high permeability values (McCave, 1985; Nowell *et al.*, 1985). The downward vertical flux of fine suspended material in the deep sea, after landing on the sea bed, will affect the permeability of these sediments. Similarly in shallow marine low energy environments accumulation of fine suspended material considerably reduces the permeability of these sediments.

In the second set of experiments the effects of microorganisms on permeability of marine sediments was studied by boosting the naturally occurring microbial communities. The enrichment columns had significantly lower permeabilities than the control columns. The greatest reduction in permeability occurred in the bacterial medium enriched cores while the photosynthetic medium enriched cores showed less decrease in permeability. The microbial effects are either caused by the physical presence of these microorganisms or in some groups by the secretion of

extracellular polymeric material which will bind sediment particles together and also block the interstices of the sediment fabric. These effects can occur in intertidal and near shore environments where high organic enrichment due to sewage outlets and agricultural land runoff carrying inorganic fertilisers occurs, and also in deeper marine sequences with upwelling currents.

The presence of fine detrital material or photosynthetic and heterotrophic microorganisms which significantly decreases the permeability of sediments will have major implications for the bio-geochemical fluxes in sediments as well as the early stages of diagenesis in marine sedimentary environments (Bauld, 1981; Friedman, 1982).

The discussion outlines the significance of our results for the natural environment in terms of subtidal and intertidal environments. It considers the mechanisms that may lead to the reduction of sediment permeability observed in the current experiments. Thirdly it takes a broader ecological view of the causes and effects of changes in sediment permeability in exposed and sheltered intertidal environments such as those in the Firth of Clyde, and relates these changes to the organic levels, microbial abundance, and invertebrate infauna in sediments.

ACKNOWLEDGEMENTS

The authors are grateful to Rockware Ltd. Ayr, Scotland, for providing Loch Aline sand, and to Dr R. Miller and Dr J. Riley for their help during the experimental stages of this work. AM sincerely and gratefully acknowledges financial support from her father Professor M. Tufail which made this study possible. The latter stages of the work were funded by the Marine Technology Directorate of SERC, U.K. (GR/G24446 MTD FOU 29). In this context the authors sincerely thank Professor David Muir Wood, now Regius Professor of Civil Engineering at the University of Bristol.

REFERENCES

Aller, R.C. (1982). The effects of macrobenthos on chemical properties of marine sediment and overlying water. Pp. 53-102 in McCall, P.L. &. Tevesz, M.J.S. (editors) *Animal-Sediment Relations*. Plenum Press, N. York.

Allison, L.E. (1947). Effect of microorganisms on permeability of soil under prolonged submergence. *Soil Science* 63, 439-450.

Anderson, J.G. & Meadows, P.S. (1978). Micro-environments in marine sediments. *Proceedings of the Royal Society of Edinburgh* 76B, 1-16.

Asher, A. & Spalding, D.F. (editors) (1982). *Culture Centre of Algae and Protozoa. List of Strains 1982*. Institute of Terrestrial Ecology, Cambridge.

ASTM. (1967). *Permeability and Capillarity of Soils*. American Society for Testing and Materials, Philadelphia.

Bauld, J. (1981). Geobiological role of cyanobacterial mats in sedimentary environments: production and preservation of organic matter. *Bureau of Mineral Resources, Journal of Australian Geology and Geophysics*, 6, 307-317.

Beard, D.C. & Weyl, P.K. (1973). Influence of texture on porosity and permeability of unconsolidated sand. *The American Association of Petroleum Geologists Bulletin* 57, 349-369.

Belyaev, S.S. & Laurinavichus, K.S. (1978). Microbial formation of methane in marine sediments. Pp 327-337 in Krumbein,W.E. (editor) *Environmental Biogeochemistry and Geomicrobiology. Vol. 1: The Aquatic Environment.* Ann Arbor Science, Michigan.

Bodman, G.B. (1937). The variability of permeability 'constant' at low hydraulic gradients during saturated water flow in soils. *Proceedings, Soil Science Society of America* 2, 45-53.

Buchanan, J.B. (1984). Sediment analysis. Pp. 41-65 in Holme, N.A. & McIntyre, A.D. (editors) *Methods for the Study of Marine Benthos 2nd edn. IBP Handbook 16.* Blackwell Scientific Publications, Oxford.

BS 1377. (1975). *Methods of Test for Soils for Civil Engineering Purposes.* BSI, London.

Byers, S.C., Mills, E.L. & Stewart, P.L. (1978). A comparison of methods of determining organic carbon in marine sediments, with suggestions for a standard method. *Hydrobiologia* 58, 43-47.

Cornée, A., Dickman, M. & Busson, G. (1992). Laminated cyanobacterial mats in sediments of solar salt works: some sedimentological implications. *Sedimentology* 39, 599-612.

Cruickshank, R., Duguid, J.P., Marmion, B.P. & Swain, R.H.A. (eds.) (1975). *Medical Microbiology. The Practice of Medical Microbiology.* 12th edtn. Vol 2. Churchill Livingstone, Edinburgh.

Duinker, J.C., van Eck, G.T.M., & Notting, R.F. (1974). On the behaviour of copper, zinc iron, and manganese and evidence for mobilization processes in the Dutch Wadden Sea. *Netherlands Journal of Sea Research* 8, 214-239.

Fenchel, T. & Riedl, R.L. (1970). The surface system: a new biotic community underneath the oxidized layer of marine sand bottoms. *Marine Biology* 7, 255-268.

Fireman, M. & Bodman, G.B. (1939). The effect of saline irrigation water upon the permeability and base status of soils. *Proceedings, Soil Science Society of America* 4, 71-77.

Folsom, B.R. & Wood, J.M. (1986). Predictions for the mobility of elements in the estuarine environment. Pp. 201-214 in Lasserre, P. &. Martin, J.M. (editors) *Biogeochemical Processes at the Land-Sea Boundary.* Elsevier, Amsterdam.

Fraser, H.J. (1935). Experimental study of the porosity and permeability of clastic sediments. *Journal of Geology* 43, 912-1010.

Friedman, G.M. (1982). Evaporites as source rocks for petroleum. Pp. 385-396 in Handford, C.R., Loucks, R. G. &. Davies, G.E.(editors) *Depositional and Diagenetic Spectra of Evaporites*. A Core Workshop SEPM, Calgary.

Gupta, R.P. & Swartzendruber, D. (1962). Flow-associated reduction in the hydraulic conductivity of quartz sand. *Proceedings, Soil Science Society of America* 26, 6-10.

Halcrow, W., Mackay, D.W. & Thornton, I. (1973). The distribution of trace metals and faunas in the Firth of Clyde in relation to the disposal of sewage sludge. *Journal of the Marine Biological Association U. K.* 53, 731-739.

Heuttel, M., Roy, H., Precht, E. & Ehrenhauss, S. (2003). Hydrodynamical impact on biogeochemical processes in aquatic sediments. *Hydrobiologia* 494 (1-3), 231-236.

Hilton, J. & Whitehall, K.V. (1979). Investigating reduced hydraulic throughput of sand filters. *Effluent Water Treatment Journal* 19, 15-25.
Hobbie, J.E. & Lee, C. (1980). Microbial production of extracellular material: importance in benthic ecology. Pp. 341-346 in Tenore, K.R. & Coull, B.C.(editors) *Marine Benthic Dynamics*. University of South Carolina Press, South Carolina.
Ivanov, M.V. (1978) Influence of microorganisms and microenvironment on the global sulfur cycle. pp. 47-61 in Krumbein, W.E. (editor) *Environmental and Geomicrobiology. Vol. 1: The Aquatic Environment.* Ann Arbor Science, Michigan.
Jørgensen, B.B. (1977). Distribution of colorless sulfur bacteria (*Beggiatoa* spp.) in a coastal marine sediment. *Marine Biology* 41, 19-28.
Jørgensen, B.B. & Fenchel, T. (1974). The sulfur cycle of a marine sediment model system. *Marine Biology* 24, 189-201.
Kristiansen, R. (1981). Sand-filter trenches for purification of septic tank effluent: 1. The clogging mechanism and soil physical environment. *Journal of Environmental Quality* 10, 353-357.
Krumbein, W.E. (1983). Stromatolites - The challenge of a term in space and time. *Precambrian Research* 20, 493-531.
Lambe, T.W. & Whitman, R.V. (editors) (1979). *Soil Mechanics, SI Version.* John Wiley & Sons, New York.
Lee, M.D., Thomas, J.M., Borden, R.C., Bedient, P.B., Wilson, J.T. & Ward, C.H. (1988). Biorestoration of aquifers contaminated with organic compounds. *CRC Critical Reviews in Environmental Control* 18, 29-89.
Lein, A. Yu. (1978) Formation of carbonate and sulfide minerals during diagenesis of reduced sediments. Pp. 339-354 in Krumbein, W.E. (editor) *Environmental Biogeochemistry and Geomicrobiology. Vol. 1: The Aquatic Environment.* Ann Arbor Science, Michigan.
Lyons, W.B. & Fitzgerald, W.F. (1978) Nutrient production in nearshore tidal flat pore waters: A kinetic study. Pp. 237-244. in Krumbein, W.E. (editor) *Environmental Biogeochemistry and Geomicrobiology. Vol. 1: The Aquatic Environment.* Ann Arbor Science, Michigan.
McCalla, T.M. (1950). Studies on the effect of microorganisms on rate of percolation of water through soils. *Proceedings, Soil Science Society of America* 15, 182-186.
McCave, I.N. (1985). Properties of suspended sediment over the HEBBLE area on the Nova Scotian rise. *Marine Geology* 66, 169-188.
Meadows, A., Meadows, P.S., West, F.J.C. & Murray, J.M.H. (2000). Bioturbation, geochemistry and geotechnics of sediments affected by the oxygen minimum zone on the Oman continental slope and abyssal plain, Arabian Sea. *Deep-Sea Research* II 47, 259-280.
Meadows, P.S. (1986). Biological activity and seabed sediment structure. *Nature* 323, 207.
Meadows, P.S. & Anderson, J.G. (1968). Micro-organisms attached to marine sand grains. *Journal of the Marine Biological Association U.K.* 48 161-175.
Meadows, P.S. & Tait, J. (1989). Modification of sediment permeability and shear strength by two burrowing invertebrates. *Marine Biology* 101, 75-82.
Meadows, P.S. & Tufail, A. (1986). Bioturbation, microbial activity and sediment properties in an estuarine ecosystem. *Proceedings of the Royal Society of Edinburgh* 90B, 129-142.
Mitchell, R. & Nevo, Z. (1964). Effect of bacterial polysaccharide accumulation on infiltration of water through sand. *Applied Microbiology* 12, 219-223.
Murray, J.M.H., Meadows, A., & Meadows, P.S. (2002). Biogeomorphological implications of microscale interactions between sediment geotechnics and marine benthos: a review. *Geomorphology*, 4, 15-30.
Nevo, Z. & Mitchell, R. (1967). Factors affecting biological clogging of sand associated with ground water discharge. *Water Research* 1, 231-236.
Newell, R. (1965). The role of detritus in the nutrition of two marine deposit feeders, the prosobranch *Hydrobia ulvae* and the bivalve *Macoma balthica*. *Proceedings of the Zoological Society of London* 144, 25-45.
Nowell, A.R.M., McCave, I.N., & Hollister, C.D. (1985). Contributions of HEBBLE to understanding marine sedimentation. *Marine Geology* 66, 397-409.
Oberdorfer, J.A. & Peterson, F.L. (1985). Waste-water injection: geochemical and biogeochemical clogging processes. *Ground Water* 23, 753-761.
Okubo, T. & Matsumoto, J. (1983). Biological clogging of sand and changes of organic constituents during artificial recharge. *Water Research* 17, 813-821.
Palmer, S.N. & Barton, M.E. (1987) Porosity reduction, microfabric and resultant lithification in UK uncemented sands. Pp. 29-40 in Marshall, J.D. (editor) *Diagenesis of Sedimentary Sequences Geological Society Special Publication No. 36.* Blackwell Scientific Publications, Oxford.
Parsons, T.R., Maita, Y. & Lalli, C.M. (1984). *A Manual of Chemical and Biological Methods for Seawater Analysis.* Pergamon Press, Oxford.
Pearson, T.H., Ansell, A.D. & Robb, L. (1986). The benthos of the deeper sediments of the Firth of Clyde, with particular reference to organic enrichment. *Proceedings of the Royal Society of Edinburgh* 90B, 329-350.
Rasheed, M., Badran, M.I. & Heuttel, M. (2003). Influence of sediment permeability and mineral composition on organic matter degradation in three sediments from the Gulf of Aqaba, Red Sea. *Estuarine Coastal and Shelf Science* 57 (1-2), 369-384.
Rasheed, M., Wild, C., Franke, U., & Huettel, M. (2004). Benthic photosynthesis and oxygen demand in permeable carbonate sediments at Heron Island, Great Barrier Reef, Australia. *Estuarine Coastal and Shelf Science* 59(1), 139-150.
Richardson, M.D., Briggs, K.B., Bentley, S.J., Walter, D.J. & Orsi, T.H. (2002). The effects of biological and hydrodynamic processes on physical and acoustic properties of sediments off the Eel River, California. *Marine Geology* 182 (1-2), 121-139.
Ripley, D. P. & Saleem, Z. A. (1973). Clogging in simulated glacial aquifers due to artificial recharge. *Water Resources Research* 9, 1047-1057.
Rusch, A. & Heuttel, M. (2000). Advective particle transport into permeable sediments – evidence from experiments in an intertidal sandflat. *Limnology and Oceanography* 45 (3), 525-533.
Sanchez de Lozada, D., Vandevivere, P., Baveye, P. & Zinder, S. (1994). Decrease of the hydraulic conductivity of sand columns by *Methanosarcina barkeri*. *World Journal of Microbiology and Biotechnology* 10, 325-333.

Shaw, J.C., Bramhill, B., Wardlaw, N.C. & Costerton, J.W. (1985). Bacterial fouling in a model core system. *Applied and Environmental Microbiology* 49, 693-701.

Smith, M.J. (1981). *Soil Mechanics*, 4th edtn. George Godwin, Ltd. London.

Steeman Nielsen, E. (1952). The use of radioactive carbon (14C) for measuring organic production in the sea. *Journal Conseil international pour l'exploration de la mer.* 18, 117-139.

Strickland, J.D.H. & Parsons, T.R. (1972). *A Practical Handbook of Seawater Analysis. Bulletin 167*, 2nd edtn. Fisheries Research Board of Canada, Ottawa.

Takahashi, M. & Ichimura, S. (1968). Vertical distribution and organic matter production of photosynthetic sulfur bacteria in Japanese Lakes. *Limnology and Oceanography* 13, 644-655.

Takai, Y., Koyama, T. & Kamura, T. (1956). Microbial metabolism in reduction processes of paddy soils (Part 1). *Soil Science and Plant Nutrition* 2, 63-66.

Taylor, S.W. & Jaffé, P.R. (1990). Biofilm growth and the related changes in the physical properties of a porous medium. 1. Experimental investigation. *Water Resources Research* 26, 2153-2159.

Taylor, S.W., Milly, P.C.D. & Jaffé, P.R. (1990). Biofilm growth and the related changes in the physical properties of a porous medium. 2. Permeability. *Water Resources Research* 26, 2161-2169.

Tufail, A. (1985). Microbial aggregates on sand grains in enrichment media. *Botanica Marina* 28, 209-211.

Unesco. (1966). *Report of a Meeting of the Joint Group of Experts on Radiocarbon Estimation of Primary Production.* Unesco Technical Papers in Marine Science, No. 6.

Unesco. (1973). *A Guide to the Measurement of Marine Primary Production under some Special Conditions.* Monographs on Oceanographic Methodology, Unesco, Paris.

Vandevivere, P. & Baveye, P. (1992a). Saturated hydraulic conductivity reduction caused by aerobic bacteria in sand columns. *Journal, Soil Science Society America* 56, 1-13.

Vandevivere, P. & Baveye, P. (1992b). Effect of bacterial extracellular polymers on the saturated hydraulic conductivity of sand columns. *Applied and Environmental Microbiology* 58, 1690-1698.

Weaver, P.P.E. & Schultheiss, P.J. (1983). Vertical open burrows in deep-sea sediments 2m in length. *Nature* 301, 329-331.

Webb, J.E. (1969) Biologically significant properties of submerged marine sands. *Proceedings of Royal Society of London* B174, 355-402.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 107-114.

JAPANESE KNOTWEED *FALLOPIA JAPONICA VAR. JAPONICA (HOUTT.)* RONSE DECRAENE ON ISLE OF GREAT CUMBRAE, FIRTH OF CLYDE, SCOTLAND.

Azra Meadows and Peter S. Meadows
Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences, University of Glasgow, Glasgow G12 8QQ
Email: gbza31@udcf.gla.ac.uk and gbza21@udcf.gla.ac.uk

ABSTRACT

Japanese knotweed, *Fallopia japonica* var. *japonica* is a native of China, Japan and parts of Taiwan and Korea. It is now naturalized in Europe and North America. The species was introduced to the British Isles in 1825 as an ornamental plant but is now regarded as a pest. *Fallopia japonica* var. *japonica* is a perennial, and appears not to seed under natural conditions, spreading only by horizontal growth of rhizomes.

This paper briefly reviews the ecology of the species in England and Scotland, and then gives results of a survey carried out on the Isle of Cumbrae, Firth of Clyde, Scotland in summer 2004. Fifteen stands of the species were recorded along the coastal road that surrounds the island (B896). These range in size from less than a square meter to 3600 square meters in area, and almost all of them are on the strip of land between high tide level and the coastal road. The stands are centred in two areas, one on the west side of the island, and one on the east side of the island. The largest three stands are close to the University Marine Biology Station, Millport, which may have been the initial focus of colonisation of the island. No obvious stands of the species were noted alongside roads that cross the centre of the island, although a full scale island survey would be needed to ascertain whether the species existed elsewhere on Cumbrae.

The sizes of the stands on the east coast of the island are generally larger than those on the west coast. They represent 92.6% of the total area of the island's knotweed coastal stands, compared with 7.4% for those on the west coast. This is a startling difference. The stands were always surrounded by growth of other plants. This may inhibit increase in stand size. Bramble was prominent at sites 2, 4, 7 and 9. The stands in the coastal strip occupy about 1.5% of the total available to them.

The approximate age of the stands has been calculated using two models. Model 1, the Disc Model, assumes that the stands grow horizontally as a disc. Model 2, the Disc and Rectangle model, assumes that the stands grow horizontally as a disc until their diameter equals the width of the strip of land between high tide and the coastal road. The stands then grow horizontally as a rectangle parallel to the shore and road, expanding in area in two directions. Three rhizome growth rates were used in each model, 0.25 $m.yr^{-1}$, 0.5 $m.yr^{-1}$, and 1.0$m.yr^{-1}$. Using these two models and three growth rates infers that the largest colonies – those on the west side of the island around the University Marine Biology Station – must be many decades or even a century old.

Based on Model 1, the appropriate model for these colonies, and on the three rhizome growth rates, the 600m^2 colony is 14, 28 or 55 years old, the 900 m^2 colony is 17, 34 or 68 years old, and the 3600m^2 colony is 34, 68 or 135 years old. The 3600m^2 colony was therefore founded in 1970, 1936, or 1869. Sometime between the latter two dates is most likely, in other words during the first part of the 20th century. Based on Model 2, the appropriate model in this instance, the equivalent ages and dates for the largest colony on the west coast of the island, 232m^2, are 13, 25 and 51 years, representing dates of 1991, 1979 and 1953. Sometime between the latter two dates is most likely, in other words during the second half of the 20th century.

Our discussion of the factors that control the rate of growth of Japanese knotweed under natural conditions on the Isle of Cumbrae, and an assessment of the potential inaccuracies in our modelling, has led to an interesting conclusion. It may be possible to identify native indigenous species of plants that can be used as native inhibitor species at the periphery of Knotweed stands to slow or completely halt the growth of stands. This natural biological control method may have wide implications for the control for other aliens – especially any that grow only by rhizomeic growth like Japanese knotweed.

Finally, we include notes on currently accepted methods of control and management of Japanese knotweed, and refer to the Wildlife and Countryside Act 1981 and web sites.

INTRODUCTION

Japanese knotweed, *Fallopia japonica* var. *japonica* is a native of China, Japan and parts of Taiwan and Korea. It is now naturalized in Europe and North America. The species was introduced to the British Isles in 1825 as an ornamental plant, and was first recorded in the wild in 1886 (Beerling et al., 1994; Ingrouille, 1995; Myers & Bazely, 2003). However it is now generally regarded as one of the most pernicious weeds in Britain. The rapidity with which it has spread in Britain and its competitiveness against other species has meant that under the Wildlife and Countryside Act it is regarded as an undesirable alien (Ingrouille, 1995). There are currently three closely related species of *Fallopia* in Britain, whose characteristic features and distribution in Britain have been described by Bailey (1996).

Japanese knotweed species occur in habitats commonly impacted by man's activities. Their range of habitats includes riverbanks, woodland, sand dunes, and waste ground - including cinder

tips, china clay waste and chalk pits (Beerling, 1994). In its native Japan it colonises volcanic soils and is found growing in sulphurous soils. The species is also common in regions exposed to high concentrations of atmospheric sulphur dioxide (Yoshioka 1974; Natori & Totsuka 1984, 1988). In Britain the species grows in soils having a pH of 3 to 8, and is known to have a high tolerance of heavy metals (Kubota *et al.*, 1988). Japanese knotweed is affected by frost – which causes blackening and damage of the young shoots, and by wind (Salisbury, 1961). It is more abundant in areas of high precipitation - for example in Wales (Conolly, 1977).

Japanese knotweed is a perennial with rhizomes, and can reach 2-3m in height. The rhizomes can spread 7m from the parent and penetrate as deep as 2m into the soil. The propagation of the species in urban areas has occurred through soil contaminated with rhizome fragments, while in rivers high water velocities facilitate growth of new colonies along the banks by the same mechanism (Beerling *et al.* 1994). In some cases knotweeds out-compete native riverside plants and can choke watercourses – which in turn leads to flooding (Bright 1999).

In the Glasgow area Japanese knotweed is often conspicuous on waste ground. It also occurs along the edges of railways and roads, in gardens and parks, and along the banks of canals, rivers and lochs. We have recorded a large thicket on the landward fringe of the saltmarsh at Ardmore Point Bay, near Helensburgh, which has been there for at least fifteen years.

Within the City of Glasgow area, the species has been recorded in St Peter's Cemetery, London Road, along the Firth of Forth and Clyde canal west of Cleveden Road, and in the Hyndland and Dowanhill area of the west end of the city (Dickson, 1991; authors unpublished records).

In this paper we report the widespread occurrence of Japanese knotweed on coasts of the Isle of Cumbrae, Firth of Clyde, and using two models calculate how long the species may have been present on the island.

MATERIAL AND METHODS

A survey of the distribution of the Japanese knotweed *Fallopia japonica var. japonica* (Houtt.) Ronse Decraene was carried out around Isle of Great Cumbrae in May 2004. Starting outside the George Hotel at Kames Bay, we followed the B896 coastal road around the Island. Each site where the knotweed was observed was sequentially numbered. The size (length and breadth) and height of each knotweed stand was measured, together with a description of the health of the stand and other vegetation in the immediate vicinity. The mileage in miles from the starting point to each site was recorded.

Other roads on the island away from the coast showed no obvious stands of the species. However it is not known whether the species is present in areas that are not visible from the island's roads. This would require a large scale survey of the island and its farmland, preferably including a low level aerial survey.

Ages of stands that we observed around the coast of the island were calculated by two methods. Both methods assume an initial stand being a single stemmed plant, and both assume a constant rhizomeic growth rate horizontally outward from this single stemmed plant. Three growth rates are considered: 0.25, 0.5 and 1.0 meters per year.

The first method (Method 1) assumes that the stand grows horizontally as a disc. The second method (Method 2) assumes that the stand grows horizontally as a disc until it meets the intertidal zone on one side and the road on the other – an assumed horizontal distance of 10 m normal (at right angles) to the shore. From then onwards the stand only grows parallel to the shore, being bounded on both sides. It hence forms a progressively longer rectangle with a half disc at each end, parallel to the shore. The algebra for the general case is as follows.

Method 1.

$A_1 = (r.a)^2\pi$ Equation 1

Where A_1 = area of stand (m^2), r = rhizomeic growth rate ($m^2.yr^{-1}$), and a = age of stand in years.

This can be rearranged to calculate the age of the stand as:

$a = (A_1/(r^2\,\pi))^{1/2}$ years Equation 2

Equation 2 can be rewritten as:

$a = c_1A_1^{1/2}$ years Equation 3

where $c_1 = (r^2\,\pi)^{-1/2}$

In our case, r = 0.25, 0.5 or 1.0 m/year, so c_1 is equal to 2.257, 1.128, and 0.5642 respectively, and equation 3 becomes:

$a = 2.257A_1^{1/2}$ years, for a growth rate of 0.25 m/year Equation 4

$a = 1.128A_1^{1/2}$ years, for a growth rate of 0.5 m/year Equation 5

$a = 0.5642A_1^{1/2}$ years, for a growth rate of 1.0 m/year Equation 6

which are straight forward calculations.

Method 2

Firstly, the stand grows as a disc when $2.r.a \leq w$, the width of corridor in which the stand is growing. in our case this is the 10 m wide corridor between the intertidal zone and the road, hence:

$A_1 = (r.a)^2\pi$ m^2 Equation 7

where A_1 = area of stand (m^2), r = rhizomeic growth rate ($m^2.yr^{-1}$), and a = age of stand in years.

Secondly, when $2.r.a > w$:

$A_2 = (r.a_1)^2\pi + 2.r.w(y - a_1)$ m^2 Equation 8

where A_2 = area of stand (m^2), r = rhizomeic growth rate ($m^2.yr^{-1}$), y = total age of the stand (years), and a_1 = age of stand (years) when $2.r.a_1$ = w, in other words when the diameter of the disc ($2.r.a_1$) is equal to the width of the corridor (w).

The equation for A_2 (equation 8) can be rearranged to calculate y, the age of the stand in years as:

$y=(A_2+2.w.r.a_1-(r.a_1)^2\pi)/(2.w.r)$ years Equation 9

Equation 9 can be rewritten as:

$y = c_2A_2 + c_3$ Equation 10

where $c_2=(2.w.r)^{-1}$

and $c_3=(2.w.r.a_1 - (r.a_1)^2\pi)(2.w.r)^{-1}$

In our case, w = 10 metres, and r = 0.25, 0.5 or 1.0 m/year.

So c_2 is equal to 0.2, 0.1 and 0.05 respectively, and c_3 is equal to 4.292, 2.146 and 1.073 respectively, for r = 0.25, 0.5 or 1.0 m/year.

So:

$y = 0.2A_2 + 4.292$ years, for a growth rate of 0.25 m/year Equation 11

$y = 0.1A_2 + 2.146$ years, for a growth rate of 0.5 m/year Equation 12

$y = 0.05A_2 + 1.073$ years, for a growth rate of 1.0 m/year Equation 13

which are straight forward calculations.

RESULTS

The results of the survey are shown in Table 1, which shows the distance in miles along the coast road (B896) between each site, together with the length, breadth and area, and the average height of each stand. The minimum height of the stands was 0.5m at site 3 and the maximum height was 2m at site 7. The largest stand measured 60 x 60 m + at site 10. Site 6 was unusual because it consisted of only four sprigs, and the rest were dead stalks. Sites 2, 4, 5, 7, and 8 had evidence of last year's growth, which may indicate that they are older and well-established stands compared with sites 1, 3, 6, and 9 to11.

There are clearly two areas of the coastal strip on Cumbrae where the stands are located. One is on the east coast towards the south end of the island, and the other is on the west coast (Figure 1). The largest stand on the west coast is stand 2 at site 4 (232 m^2). The largest stand on the east coast is stand 2 at site 10 (3600 m^2). This is easily the largest stand on the island that we have seen, and may be the founder stand for the whole island.

The sizes of the stands on the east coast of the island are generally larger than those on the west coast. They represent 92.6% of the total area of the island's knotweed stands, compared with 7.4% for those on the west coast (Table 1). This is a startling difference.

The stands were always surrounded by growth of other plants. This may inhibit increase in stand size. Bramble was prominent at sites 2, 4, 7 and 9. The occurrence of swarm of large black flies within the stand at site 1 was of interest. This may be because the site was on the edge of grass, near the Boat Yard, where decaying seaweed or other decomposing organic material had attracted the flies. The vertical growth of the stands was fairly constant. Most of the larger stands were 1.5 to 2.0 metres in height with some of the smallest colonies being only 1.0 meter high.

Two models were developed to obtain an assessment of the approximate age of the stands based on their areas: model 1 - the disc model, and model 2 – the disc and rectangle model. Both models are of general application. The details of the development of the two models is given in the Materials and Methods section. Stands increase in size by rhizomes growing horizontally out from the colony. For our purposes, three rates of horizontal rhizomeic growth were incorporated into the two models: $0.25 m.yr^{-1}$, $0.5 m.yr^{-1}$, and $1.0 m.yr^{-1}$. The disc model (Model 1) assumes that the stand grows as a disc of increasing diameter (materials and methods, equations 1 to 6).

The disc and rectangle model (Model 2) is based on different criteria (materials and methods, equations 7 to 13). Almost all of the stands on the Isle of Cumbrae that we recorded occur on the strip of land between the highest level of tides, Extreme High Water Springs (EHWS), and the coastal road that runs around the island. This places constraints on the growth of the stands. Stands can only grow as an expanding disc until they reach a diameter, which is equal to the breadth of the strip of land – the distance from EHWS to the coastal road. The strip of land is between about 5m and 15m in width. So once a colony reaches this diameter it can only grow parallel to the shore in each direction. It does so as a rectangle of increasing length parallel to the shore whose shorter side is constant and equal to the breadth of the strip. The disc and rectangle model (Model 2), includes this restriction, and for simplicity our calculations have been based on the strip being 10m wide, although the model can accommodate any breadth of strip in its general algebraic form (equations 8, 9, and 10).

Figures 2 and 3 show the relationship between the area of the stand and its age based on the disc model and the disc and rectangle model respectively. In each figure the upper line represents a growth rate of $0.25 m.yr^{-1}$, the middle line a growth rate of $0.5 m.yr^{-1}$, and the lowest line a growth rate of $1.0 m.yr^{-1}$. The vertical arrow in each figure represents the area of the largest stand, Site 10 stand 2 ($3600 m^2$).

Tables 2 and 3 show the observed areas of each of the stands on the Isle of Cumbrae (column 1) and their calculated ages using Model 1, the disc model, and Model 2, the disc and rectangle model, for $0.25 m.yr^{-1}$, $0.5 m.yr^{-1}$, and $1.0\ m.yr^{-1}$. These calculations highlight the wide range of ages that are available for consideration in relation to the whole population of Knotweed stands on the coastal belt of the Isle of Cumbrae,. They also have implications for the approximate date of first colonisation of the island. In this context it is worthy of note that the three largest colonies do not lie in the narrow strip of land between the coastal road and extreme high water springs, and their ages are more appropriately taken as those measured by model 1 (Table 2). These have areas of approximately $600m^2$ $900m^2$ and $3600m^2$, respectively.

Based on Model 1, the appropriate model for these colonies, and on the three rhizome growth rates, the $600m^2$ colony is 14, 28 or 55 years old, the 900 m^2 colony is 17, 34 or 68 years old, and the $3600m^2$ colony is 34, 68 or 135 years old. The $3600m^2$ colony was therefore founded in 1970, 1936, or 1869. Sometime between the latter two dates is most likely, in other words during the first part of the 20th century. Based on Model 2, the appropriate

	Distance (miles)	Japanese knotweed Stand Description	Size (m) (L x B)	Area (m^2)	Ht. (m)
South end of island – Site 1.					
1	0.4	On sea edge of grass, just before Boat Yard, about 1000 large black flies swarming within the stand	1 x 0.5	0.5	1
West coast of island – Sites 2 to 6.					
2	3.2	Fintry Bay (near the Tea Rooms), old stand, evidence of last years growth, with brambles, no black flies.	13 x 13	169	1.8
3	3.4	Young stand near rocky cliff, no black flies	1 x 0.4	0.4	0.5
4	3.8	Two stands opposite the painted Red Indian's face. Stand 1. One small stand, evidence of last years growth. Stand 2.One large stand, evidence of last years growth. Both stands separated by brambles.	 8 x 4 29 x 8	 32 232	 1.8 1.9
5	4.2	Near orchid stand, plus 7 white geese nesting, evidence of last years growth plus old dead stand.	11 x 6	66	1.8
6	4.3	Only four sprigs, lot of scattered dead stalks	-	< 0.1	1
Total area of stands on west coast of island: c. 500 m^2		**7.4% of whole area of stands in coastal belt.**			
East coast of island – Sites 7 to 11.					
7	8.5	Opposite Hunterston Ore Terminal. Stand 1 old growth from last year plus 1m wide band of new growth towards road, stand surrounded by brambles. Stand 2 same as stand 1, but larger in size. Stands separated by brambles. Brambles also growing on the LHS of stand facing the sea.	 11 x 10 24 x 10	 110 240	 2 2
8	8.6	Stand has dead plus living stalks	10 x 10	100	1.5
9	8.65	100yds east of Lion Rock, young stand surrounded by bramble	18 x 15	270	1.2
10	9.2	Three stands just past the UMBS Specimen Centre. Stand 1 Stand 2 Stand 3 On landside of road W of Ravenscraig	 30 x 30 60 x 60 30 x 20	 900 3600 600	 1.8 to 1.9
11	9.3	Just E of UMBS caretaker's house on wall	20 x 20	400	1.6
Total area of stands on east coast of island: 6220 m^2		**92.6% of whole area of stands in coastal belt.**			
Grand Total Area of stands in coastal belt of whole island: 6720 m^2 (100%)					

Table 1. Distribution of Japanese knotweed on the island of Great Cumbrae, and sizes of stands. Note: Stand 1 is shown in the bottom photograph on the back cover of this issue.

model in this instance, the equivalent ages and dates for the largest colony on the west coast of the island, 232m^2, are 13, 25 and 51 years, representing dates of 1991, 1979 and 1953. Sometime between the latter two dates is most likely, in other words during the second half of the 20th century.

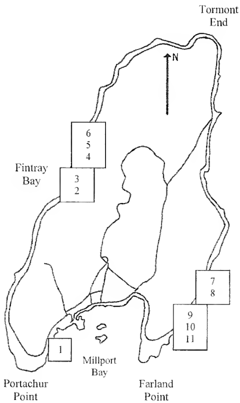


Figure 1. Isle of Great Cumbrae. Firth of Clyde. Outline drawing showing positions of sites 1 to 11 at which stands of Japanese Knotweed was identified on the coast road. North arrow represents 1000m in length. Lines within the outline of the island are roads. The coast road is very close to the intertidal zone – in some cases no more than a few metres. Its average width is about 15 metres.

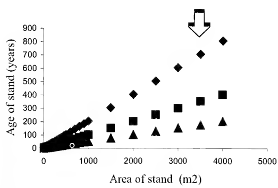


Figure 2. Model 1. Theoretical relationship between area of stand and age of stand based on the stand growing outwards as a disc (see text for details). Upper line, rhizome growth rate 1.0m.yr^{-1}. Middle line, rhizome growth rate 0.5 m.yr^{-1}. Lower line, rhizomeic growth rate rhizome growth rate 0.25m.yr^{-1}.The arrow shows the area of the largest stand recorded on the Isle of Cumbrae during the survey (3600m^2).

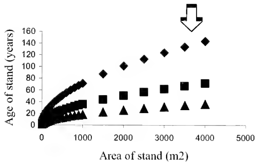


Figure 3. Model 2. Theoretical relationship between area of stand and age of stand based on the stand growing outwards as a disc until it reaches a diameter of 10m, then growing as a rectangle of fixed shorter side 10m (see text for details). Upper line, rhizome growth rate 1.0m.yr^{-1}. Middle line, rhizome growth rate 0.5 m.yr^{-1}. Lower line, rhizomeic growth rate rhizome growth rate 0.25m.yr^{-1}. The arrow shows the area of the largest stand recorded on the Isle of Cumbrae during the survey (3600m^2).

Observed area of stand (m^2)	Calculated age of stand (years)		
	Rhizome growth rate (0.25 m^{2}yr^{-1})	Rhizome growth rate (0.5 m^{2}yr^{-1})	Rhizome growth rate (1.0 m^{2}yr^{-1})
0.4	1.4	0.71	0.36
0.5	1.6	0.80	0.40
1	2.3	1.1	0.56
32	12.8	6.4	3.2
62	17.8	8.9	4.4
100	22.6	11.3	5.6
110	23.7	11.8	5.9
169	29.3	14.7	7.3
232	34.4	17.2	8.6
240	35.0	17.5	8.7
270	37.1	18.5	9.3
400	45.1	22.6	11.3
600	55.3	27.6	13.8
900	67.7	33.8	16.9
3600	135.4	67.7	33.9

Table 2 . Observed areas and calculated ages of stands on the Isle of Cumbrae.
Ages calculated by Model 1, the disc model, for rhizome growth rates of 0.25m.yr^{-1}, 0.5 m.yr^{-1}, and 1.0m.yr^{-1}.

Observed area of stand (m^2)	Calculated age of stand (years)		
	Rhizome growth rate (0.25 m^2yr^{-1})	Rhizome growth rate (0.5 m^2yr^{-1})	Rhizome growth rate (1.0 m^2yr^{-1})
0.4	1.4	0.71	0.36
0.5	1.6	0.80	0.40
1	2.3	1.1	0.56
32	12.8	6.4	3.2
62	17.8	8.9	4.4
100	24.3	12.1	6.1
110	26.3	13.1	6.6
169	38.1	19.0	9.5
232	50.7	25.3	12.7
240	52.3	26.1	13.1
270	58.3	29.1	14.6
400	84.3	42.1	21.1
600	124.3	62.1	31.1
900	184.3	92.1	46.1
3600	724.3	362.1	181.1

Table 3. Observed areas and calculated ages of stands on the Isle of Cumbrae.
Ages calculated by Model 2, the disc and rectangle model, for rhizome growth rates of 0.25m.yr^{-1}, 0.5 m.yr^{-1}, and 1.0m.yr^{-1}.

DISCUSSION

The easy mode of dispersal together with its growth by rhizomes, has made Japanese knotweed a successful coloniser, and the species now has a wide distribution in the United Kingdom. However the species may be towards the limit of its northern distribution in the British Isles as river habitat surveys have shown that Scotland has a quarter as much knotweed as England and Wales (Dawson & Holland 1999). Myers and Bazely (2003) have produced four very interesting maps of the spread of the species across the United Kingdom including Scotland, for 1900, 1920, 1940, and 1970 (Figure 4). These show that Japanese Knotweed has been in Scotland since at least 1920, with one of the records in the 1920 distribution map appearing to be located in the greater Glasgow area. Our own estimates of the age of the largest stands of the species on the Isle of Cumbrae, which we discuss below, accord with this as they suggest that the species has been on the island since the early part of the 20th century. It is difficult to speculate about local factors that might control the spread of Japanese Knotweed or limit the size of its stands under natural conditions. Other plant species and also animal species must surely play a part. On the Isle of Cumbrae, brambles were noted around the edge of a number of stands, so these may be important in inhibiting the spread of the species' rhizomes. Insects may also play a role. A number of insects, including species of Hemiptera, Lepidoptera and Coleoptera have been recorded feeding on Japanese knotweed in Britain (Emery 1983) and our own observations of black flies on the plant may have been linked to the flies feeding preferences.

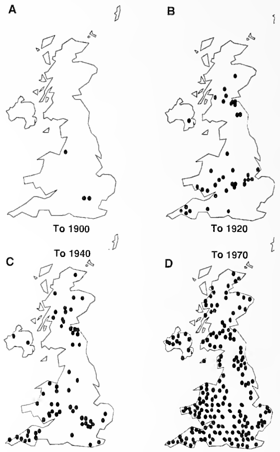


Figure 4. Historical spread of Japanese Knotweed in England, Scotland and the Isle of Man since 1900. (Myers & Bazzely, 2003, Box 2.7 page 33. Mpped by the Biological Records Centre, Monkswood, UK., After Beerling et al., 1994).

Sheep and cattle are known to graze on the shoots of the Japanese knotweed and reduce shoot density in early summer (Beerling 1990). Horses and donkeys also graze on the species although the rhizome is said to be toxic to certain livestock (Cooper & Johnson 1984). One or more of these mammal species may graze on the Japanese knotweed stands on Cumbrae, as farms on the island raise cattle and sheep. However it is not clear whether this takes place. Almost all of the knotweed stands are on the seaward side of the road and the sheep and cattle are restricted to the landward side of the road by fencing. There are two explanations for this distribution of the stands. Sheep and cows on the landward side might graze down any stands that attempted to establish themselves on the landward side. Alternatively the soil, vegetation and microclimate on the seaward side of the road might be more suitable to

knotweed. It is an interesting and unexplained phenomenon.

The occurrence of Japanese knotweed at two foci on the island, one on the east coast and one on the west coast, is interesting. The largest stands are around the University Marine Biological Station between Lion Rock and Farland Point, and so this area might have been the initial point of colonisation of the island. Colonies on the western shore may have been seeded from here with the first one there being at site 4. Alternatively, the two sides of the island may have been colonised entirely independently from the mainland. The lack of the species on the northern coast of the island is interesting, and may be related to prevailing weather conditions there. The same may be true for the lack of stands on the southern coast at Portachur Point.

It is interesting to calculate the total area of the 10 metre wide coastal strip between the coastal road and high tide that is currently occupied by knotweed stands. Assume that this coastal strip is about 11 km long. Then its area is about 11,000x10 = 110000 m^2 in area. The area of the stands excluding the three largest ones (600, 900, and 3600 m^2 which are not in this strip) is 1617 m^2. This represents 1617x100/110000% = 1.47%. Hence the current area occupied by Japanese knotweed stands in the coastal strip is about 1.5% of that which is potentially available for colonisation.

Our estimates of the ages of the stands on Cumbrae using the two models that we have developed can only be approximate. There are a number of reasons for this. Firstly, the strip of land between high tide and the coastal road had been taken as being 10 metres wide. Although this is a reasonable estimate of the average width of the strip, the strip varies in width around the island. So if model two is applied to a stand that is growing in an area where the strip is significantly greater or less than 10 metres in width, then the model 2 estimate of its age will be inaccurate. We do not consider that this will make more than a 10 to 15 percent difference to our estimates of age. Secondly, our three chosen rhizome growth rates of $0.25m.yr^{-1}$, $0.5m.yr^{-1}$, and $1.0m.yr^{-1}$, although they broadly span the usually accepted growth rates, are assumed to be constant. This cannot be the case for any plant growing under natural conditions, as cyclical or long term changes in weather from year to year can often have unpredictable effects on plant growth. It would not be easy to assess the influence of these changing climatic factors on the stands of Japanese Knotweed on Cumbrae. Thirdly, the growth of the stands might be significantly reduced by competing species of plants at their outer perimeter of the stand. This effect may be important. Bramble around some of the stands, for example stands 4, 7 and 9 on the west coast of the island, looks as if it may provide a barrier to further outward growth.

There may be wider implications. Alien plants such as Japanese Knotweed are notoriously difficult to control. Perhaps a biological control method using native species of plants with the potential to inhibit Japanese Knotweed spread should be studied. The first step would be to identify the plants at the periphery of a number of stands, and then to follow the growth of the stand and the surrounding plants over a several years. Those species of surrounding plants that inhibited growth of the Japanese Knotweed stands could then be cultivated and planted around Japanese Knotweed stands that required control. This natural biological control method may have wide implications to other plants that for one reason or another are deemed to require control of their spread. The method would be particularly relevant to species that grow mainly or only by rhizomeic growth – such as Japanese knotweed.

THE CONTROL AND MANAGEMENT OF JAPANESE KNOTWEED

We have added the following short section as we consider that it is important to publicise the need for control and management of the species.

The Wildlife and Countryside Act 1981 provides the primary controls on the release of non-native species into the wild in Great Britain. It is an offence under section 14(2) of the Act to 'plant or otherwise cause to grow in the wild' any plant listed in Schedule 9, Part II. This includes Japanese knotweed. Japanese knotweed spreads by rhizomes which propagate rapidly. It is therefore relatively easy to control colonies at an early stage during their development. The plant material should be contained and treated on site - in particular in a river situation start upstream and work progressively downstream. Chemical control is recommended because the root system is often widespread and after physical disturbance can easily regenerate new plant growth (Dawson & Holland 1999).

The Environmental Agency's Code of Pract (Environmental Agency web site) gives detailed information for the management, destruction an disposal of Japanese knotweed. It suggests us chemical control near water, with herbicides containing glyphosate. Other suggested alternativ are cutting, pulling, grazing and digging.

The following points are important, and are tak from the Environmental Agency's web site:

- Failure to manage and dispose of Japan knotweed responsibly may lead to prosecution.
- Spreading Japanese knotweed is harmful native plants and animals.
- Failure to manage Japanese knotweed on development site may result in eventual structu damage, especially to tarmac surfaces.

In this context it is interesting to note that to date th is no reference to Japanese knotweed on the Scott Environmental Protection Agency's web site.

Web sites

Cornwall County Council
http://www.cornwall.gov.uk.

Cornwall Knotweed Forum
http://www.cornwall.gov.uk/environment/knotweed/
(Useful advice for Householders/Landowners)

Devon County Council
http://www.devon.gov.uk
http://www.ex.ac.uk/knotweed/knotweed_dos.htm
(Knotweed Do's and Don'ts)

Environmental Agency
http://www.environment-agency.gov.uk/subjects/conservation,
http://www.environment-agency.gov.uk/subjects/conservation/840870/840894/840941/?version=1&lang=_e
Search for alien species, then Japanese knotweed.

Exeter University
http://www.ex.ac.uk/knotweed/Introduction.htm

Japanese Knotweed Alliance
http://www.cabi-bioscience.org/html/japanese_knotweed_alliance.htm#control
(Control Methods, Biological Control Practices)

Royal Horticultural Society
http://www.rhs.org.uk

Royal Horticultural Society Advice on Japanese knotweed
http://www.rhs.org.uk/advice/profiles0604/japanese_knotweed.asp

Waste Aware. Hertfordshire Partnership
http://www.wasteaware.org.uk/db/material.cfm?id=91

In summary, initiatives should be focussed on legislation, strategic policies and practical advice (Coleshaw, 2001). It is our responsibility to ensure that invasive and introduced plant species such as Japanese knotweed are managed and controlled effectively.

This needs well-planned procedures that include assessment, prevention and remediation (Myers & Bazely 2003). The presence of these species should not disturb ecosystem function and stability.

ACKNOWLEDGEMENTS

We thank John Allen, Jim Atkinson and Geoff Moore for their comments on the presence of Japanese knotweed on Cumbrae.

REFERENCES

Bailey, J.P., Child, L.E. & Conolly, A.P. 1996. A survey of the distribution of *Fallopia x bohemica* (Chrtek & Chrtkova) J. Bailey (Polygonaceae) in the British Isles. *Watsonia* 21, 187-198.

Beerling, D.J. (1990). *The ecology and control of Japanese knotweed (Reynoutria japonica Houtt.) and Himalayan Balsam (Imaptiens glandulifera Royle) on river banks in South Wales*, Ph.D. thesis, University of Wales, Cardiff.

Beerling, D.J., Bailey, J.P. & Connnolly, A.P. (1994). *Fallopia japonica* (Houtt.) Ronse Decr-aene. *Journal of Ecology* 82, 959-979.

Bright, C. (1999). *Life Out of Bound, Bioinvasion in a Borderless World.* Earthscan. Earthscan. Publications Ltd., London.

Coleshaw, T. (edit) (2001). *The Practical Solutions Handbook for Removal of Invasive Plant Species*: FACT project / English Nature.

Conolly, A.P. (1977). The distribution and history in the British Isles of some alien species of *Polygonum* and *Reyoutria. Watsonia* 11, 291-311.

Cooper, M.R. & Johnson, A.W. (1984). *Poisonous Plants in Britain and their Effects on Animals.* Ministry of Agriculture, Fisheries and Food, HMSO, London.

Dawson, F.H. & Holland, D. (1999). The distribution in bank side habitats of three alien invasive plants in the U.K. in relation to the development of control strategies. *Hydrobiologia* 415, 193-201.

de Waal, L.C., Child, L.E., Wade, P.M. & Brock, J.H. (eds.) (1994). *Ecology and Management of Invasive Riverside Plants.* John Wiley & Sons, Chichester.

Dickson, J.H. (1992). *Wild Plants of Glasgow.* Mercat Press, Edinburgh.

Dickson, J.H., Macpherson, P. & Watson, K.J. (2000). *The Changing Flora of Glasgow: Urban and Rural Plants Through the Centuries.* Edinburgh University Press, Edinburgh.

Dickson, J.H. (1996). Historical Ecology of the British Flora (Book Review). *The Glasgow Naturalist* 23(1), 64-65.

Dickson, J.H. (2001). Alien vascular plants in Scotland: Concepts and consequences – Scotland no Hawaii. *The Glasgow Naturalist* 23, Alien Species – Friends or Foes, supplement, 2-12.

Emery, M.J. (1983). *The Ecology of Japanese knotweed, its Herbivores and Pathogens and their Potential as Biological Control Agents.* M.Sc. thesis, University of Wales, Bangor.

Gilbert, O. (2001). Figs, Japanese knotweed and Himalayan balsam enhance the urban ecology of Sheffield. *The Glasgow Naturalist* 23, Alien Species – Friends or Foes, supplement, 52-56.

Hart, M.L., Bailey, J.P., Hollingsworth, P.M. & Watson, K.J. (1997). Sterile species and fertile hybrids of Japanese knotweeds along the River Kelvin. *The Glasgow Naturalist* 23(2), 18-22.

Ingrouille, M. (1995). *Historical Ecology of the British Flora.* Chapman & Hall, London.

Kubota, K., Nishizono, H., Suzuki, S. & Ishii, F. (1988). A copper-binding protein in root cytoplasm of *Polygonum cuspidatum* growing in a metalliferous habitat. *Plant Cell Physiology* 29, 1029-1033.

Myers, J.H. & Bazely, D.R. (2003). *Ecology and Control of Introduced Plants.* Cambridge University Press, Cambridge.

Natori, T. & Totsuka, T. (1984). An evaluation of the high resistance *Polygonum cuspidatum* to sulphur dioxide (SO_2). *Japanese Journal of Ecology* 34, 153-159.

Salisbury, E.J. (1961). *Weeds and Aliens.* Collins, London.

Yoshioka, K. (1974). Volcanic vegetation. Pp. 237-267. *Flora and Vegetation of Japan* in Numata, N. (editor) Elsevier, Amsterdam.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 115-118.

THE EARLY STAGES IN THE DEVELOPMENT OF AN OX-BOW LAKE BESIDE THE RIVER ENDRICK

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 0DX

[River Endrick below Drymen *Bridge*] ….. "*Its loops lengthen, sliding round in one U-bend after another, so that anyone who keeps to the waterside finds himself walking half a mile or more and returning to within a few yards of the spot where he started*".

'A River of Many Surprises'
W Kenneth Richmond (1959).

ABSTRACT

The first stages in the development of an ox-bow lake alongside the River Endrick in lowland Scotland are described and illustrated. Also given is a species list of the water's edge and aquatic plants which have colonised the newly created backwater over a twenty-year period.

INTRODUCTION

The River Endrick or Endrick Water, which rises in the Fintry-Gargunnock Hills of lowland Stirlingshire, cannot be considered one of Scotland's major water courses, for in length it is barely 50 km from source to mouth. Yet because of the river's diverse form and dynamic behaviour, the Endrick has been the subject of a number of geomorphological and biological studies (e.g. Bluck, 1971; Maitland, 1966 & 1996; Mitchell, 1994 & 2001). What has proved to be of special appeal to the geographer is the series of sinuous meanders along the lower reaches of the river before it discharges into Loch Lomond. Ample evidence is to be found in this section that the Endrick is continually migrating back and forth across the valley floor, in the process working and re-working the alluvial sediments of silts and fine sands which have been deposited on the river's flood plain in the past. The present paper focuses on just one example of the many changes in the course of the Endrick which have taken place over thousands of years.

RECENT CHANGES IN RIVER FLOW

Measurements taken from Ordnance Survey maps published from the mid 19th century would seem to indicate that, until about 1970, the scroll-like curves of the River Endrick which form the southern boundary to the Drymen Show Field (NS 470873), immediately downstream of Drymen Bridge, were shifting their positions at a mean annual rate of just under 0.5m. Over the next two decades however, the rate of river bank erosion on the concave side of each meander significantly quickened, without doubt the result of an increase in the occurrence of spates. This stepping up in the frequency of maximum flow can be attributed to a combination of higher than usual rainfall experienced in the region, and more rapid run-off from the catchment area in the wake of land drainage schemes for agriculture and plantation forestry in Strathendrick reaching a peak.

From the early 1980s the author began periodic observations on one well developed loop meander beside the Show Field, the gradually narrowing 'neck' at its base nearing the point of being cut through (Fig. 1). A visit to the study area in October 1983 was rewarded with the sight of the last 5.5m of river bank collapsing under pressure from a powerful surge of flood water following heavy rain (Fig. 2), in turn setting this part of the river on a more direct course. Occasional checks continued to be made on the now abandoned channel or backwater, as it progressed through the early stages of being sealed off from the main river through the accumulation of sediments originating from other eroding banks further upstream (Fig. 3). When separation is complete, the feature will be referred to as an ox-bow lake.

COLONISATION OF THE BACKWATER BY AQUATIC PLANTS

The often fast-flowing current having previously made the sandy substrate of this stretch of the river too unstable for the establishment of macro-vegetation, particular attention was paid to the gradual colonisation by plant life of the newly created slow-flowing to still backwater (Fig. 4). In the summer of 2003 a total of twenty or so native water's edge and aquatic plants were present, representing on average one additional species per year.

Table I. Water's edge and aquatic species recorded in the Show Field backwater in 2003.

Ranunculus hederaceus
Persicaria amphibia
P. hydropiper
Lythrum portula
Apium inundatum
Myosotis scorpioides
Stachys palustris
Mentha aquatica
Callitriche spp.
Veronica beccabunga
Alisma plantago-aquatica
Lemna minor
Eleocharis palustris
Carex rostrata

C. vesicaria
Glyceria fluitans
Phalaris arundinacea
Alopecuris geniculatus
Sparganium emersum
S. erectum

It seems highly unlikely that the macrophyte community at this site will ever develop to the state of maturity as the Low Mains ox-bow lake (Fig. 5), some 7 km further downstream (NS 442882), for the Show Field backwater is already under threat from another meander moving across the Endrick's flood plain. By the summer of 2003, the steadily eroding face of the active meander had little more than 50m to advance before the river will be at the stage of breaking into and rejuvenating much of its former channel, inevitably interrupting the plant succession.

ACKNOWLEDGEMENTS

My thanks to Norman Tait for preparing the project photographs for publication.

REFERENCES

Bluck, B.J. (1971). Sedimentation in the meandering River Endrick. *Scottish Journal of Geology* 7, 93-138.

Maitland, P.S. (1966). *The Fauna of the River Endrick.* Blackie, Glasgow.

Maitland, P.S. (1996). The River Endrick – then and now, monitoring by photography. *Freshwater Forum* 7, 7-22.

Mitchell, J. (1994). 'The River Endrick below Drymen Bridge' in *167th Annual Show at Drymen.* Strathendrick Agricultural Society.

Mitchell, J. (2001). *Loch Lomondside* (New Naturalist 88). Harper Collins, London.

Figure 1. River Endrick: the Show Field loop meander with its neck still intact (3/10/1982).

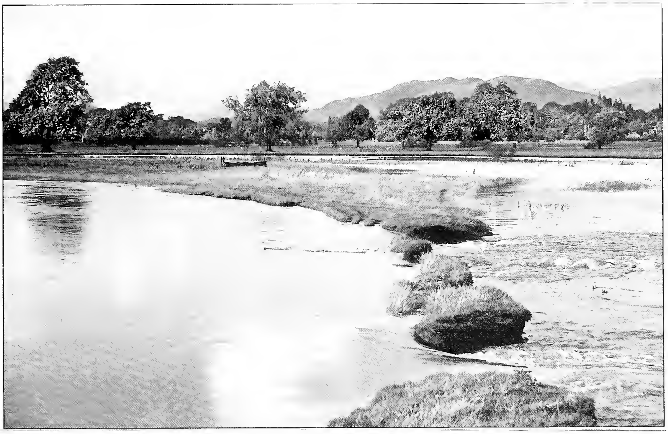


Figure 2. The river in full flow, breaking through all that remains of the meander neck (12/10/1983),

Figure 3. Sediments accrete most rapidly at the outlet to a newly abandoned river channel (9/9/1990).

Figure 4. An early stage in the vegetation succession at the Show Field backwater (22/8/2003).

Figure 5. The long established ox-bow lake at Low Mains beside the River Endrick (18/5/1984).

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 119-129.

ALEXANDER PATIENCE (1865-1954): GLASGOW'S LITTLE-KNOWN EDWARDIAN CARCINOLOGIST

P. Geoffrey Moore[1] and E.Geoffrey Hancock[2]
[1]University Marine Biological Station Millport, Isle of Cumbrae, KA28 0EG
[2]Hunterian Museum (Zoology), Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ

ABSTRACT

An appreciation is furnished of the life and scientific contributions of Alexander Patience (1865-1954), an amateur carcinologist who was active in the Glasgow area during the first decade of the twentieth century. Extensive biographical details (including some genealogical information) are given for the first time and his involvement both with the Marine Station at Millport, and with scientific professionals in his field are explored. An effort is made to explain the reason behind the abrupt termination of his output of publications on Crustacea. A full, annotated, bibliography of his published work is presented.

INTRODUCTION

Despite the fact that Alexander Patience made a significant early twentieth century contribution to the study of Crustacea in the West of Scotland (see Bibliography), no general appreciation of his life has ever been published. It is over a decade ago now since one of us (Hancock, 1992) furnished the only contribution that has examined Patience's carcinological legacy but that paper focused only on his work on woodlice (slaters). That selection reflected the fact that there is a Crustacea collection of his (1908-1910), including woodlice, in the Hunterian Museum collections of Glasgow University. Appropriately, one woodlouse species in the British list, as currently constituted, commemorates him; that is *Miktoniscus patiencei* Vandel, 1946 (Hopkin, 1991). Such a memorial seems particularly apt since this rare trichoniscid lives in salt marshes, i.e. at the interface between the terrestrial and marine environments (Hopkin, 1991), emphasising the twin strands of Patience's carcinological interests. His woodlice contributions notwithstanding, it was especially heartening to PGM (an avowed amphipodologist) to discover in a letter that Patience had written to W. T. Calman at the Natural History Museum in London in September 1909, referring to an offer of material from Simpson, that Patience had told Simpson 'I would be delighted to have the Amphipoda, to which group I am greatly attached [BM(NH) archives; ref. DF252/7].

This paper seeks to furnish as rounded an assessment of the man as possible, given the acknowledged paucity of biographical source material (Hancock, 1992). We have failed so far to unearth any likeness of Patience, though it remains a possibility that he may be numbered among the, largely unnamed, group that was photographed at the time of a visit to the Millport Marine Station made during the British Association for the Advancement of Science meeting held in Glasgow in 1901 (which photograph by Paul Rottenburg is currently displayed at the entrance to the foyer to the Robertson Museum at U.M.B.S.M.). Interestingly, the 'society photographer' Paul Rottenburg owned 2 Prince Albert Road, Dowanhill, Glasgow (postal code now G12 9JX) in the middle and late 19^{th} century. The large first floor billiard room to the rear of the property (now the sitting room of the Mews) contains Rottenburg's initials finely carved in plaster at the four corners of the ceiling. Furthermore the wooden internal roof of the billiard room at 2, Prince Albert Road almost exactly mimics on a slightly smaller scale the fine wooden internal roof of the University Marine Biological Station's library (pers com. Peter Meadows).

PATIENCE FAMILY GENEALOGY

Patience is an unusual surname in Scotland (as will be attested by the perusal of any Scottish telephone directory, except that for the Highlands & Islands area). The family has its stronghold in the northeast, in Ross and Cromarty particularly around Avoch (pronounced Och!), an attractive former herring-fishing village on the southern shore of the Black Isle. The family appears to have originated from French stock (note: the nearby Beauly Priory was built by French monks in 1230). An Alexander Patience features in Avoch's earliest written records (the Old Parish Registers), going back to *ca* 1727 (Jane Patience & Alexandra Norton, pers. comms to PGM). Jane Patience also notes that there is a chateau Patience at Ste. Avit near to Mont de Marsan, west of Toulouse that belonged to the de Mesmes family and that Jean de Mesmes held the title sieur de Patience in the sixteenth century. She thinks that the Patiences came to southern England from southern France and that some men came North with Oliver Cromwell when his forces built the Inverness Citadel *ca* 1650, allegedly using stone from Avoch Castle, Beauly Priory and Fortrose Cathedral. There were certainly Patiences in Petty (Inverness-shire) in 1704 (Alexandra Norton, pers. comm. to PGM). There was much coming and going between Scotland and France, where, until about 1670, the French government accorded to the Huguenots the privileges promised by the Edict of Nantes in 1598 (Mackie, 1954). These Protestant refugees, latterly fleeing religious persecution after the Edict's revocation under Louis XIV, who had come to Scotland by 1707 were skilled artisans, mainly weavers.
[http://www.bearne.com/history/huguenot.asp].

Particular frustration (and scope for confusion) arises when tracing the genealogy of this family, since many Patience males have traditionally been called Alexander (also Andrew, Donald). Until about 1950 there was a relatively small pool of Christian names in circulation in Scotland, with second names - that so assist the genealogist - being unusual and name allocation within families often following a complex protocol, e.g. first son being named after father's father, third son after father (Nicolson, 2004). Alexander (Alex, Alec, Sandy) was certainly, and still remains, one of the commonest given names. For instance, there are nine Alexander Patiences listed in the 1851 census returns for Avoch alone as well as two more elsewhere in the Black Isle at that date. Locally in Avoch, confusion is avoided conversationally by substituting colloquial by-names (also called teenames) [http://www.nefa.net/archive/fishing/fisherfolk.htm]; nicknames that also pass down through the generations (Patience family teenames include Canky, Pallats, Cainters, Tots, Totties, Muckle Dol; Alexandra Norton, pers. comm. to PGM). Alex Norton has made a particular study of the genealogy of the various Patience lineages and we have drawn heavily on her knowledge and civic archives in assembling the following curriculum vitae. She was unaware of any teename appropriate to 'our' Alexander Patience but then he was some generations removed from his Avoch heritage (see below).

ALEXANDER PATIENCE OF GLASGOW

'Our' Alexander Patience was born in Inverness (3 Anderson St) on 3 December 1865 to James (then a ship steward) and Jessie Patience (née Paterson). His great-grandparents had married at Avoch in 1796. His father, James Patience, who had been born in Dornoch, became a river pilot and shipmaster. One of a family of seven children, Alexander grew up among the ships of the Clyde, then as now the premier commercial waterway of Scotland. By 1870, vessels of 6.7 m (22 ft) draught and 1,000 tons burthen could negotiate the River Clyde right up to Glasgow in the space of one tide, utilising the artificially deepened channel (Ellis, 1972; McCarroll, undated). The 1881 census lists the Patience abode as 25 West Stewart St, W. Greenock. Shipping and maritime trading industries were booming locally ('Greenock for sugar and ships' as Dow & Kinniburgh (1962) put it). By the end of the nineteenth century, the dock at Greenock covered 482 ha (195 acres; Davidson, 2003). The town became the main embarkation port for emigrants from Scotland, while shipbuilding became synonymous with the Clyde. Greenock was also the traditional portal through which itinerant Highlanders funnelled before bestriding the globe; a town where schooling opportunities included the Highlanders' Academy (Dow & Kinniburgh, 1962). Alexander was still living with his parents, when aged 25 years, in 1891 (having by then moved to 68 Pollock St, Kinning Park, Glasgow); along with his 21-year old sister Jane. [Note: there is potential for confusion since another Alexander Patience was born on 11 May 1877 in Glasgow. He was 'our' Alexander's second cousin]. Our man's first marriage (entered into aged 31 years, registered at Plantation, Lanarkshire) to Elizabeth MacKinnon, a schoolmistress aged 29 years, took place on 22 September 1897 at the (Gaelic) Free Church, Govan. He was then styling himself as a house factor's manager, living at 1 Clutha St, Govan. The 1901 census, however, records him and his wife temporarily near the Ayrshire coast with their first-born, while expecting their next issue, at Meadowfoot, West Kilbride. Sadly, his first marriage ended less than seven years later, with Elizabeth's death at Govan from endocarditis, aged only 36 years, on 7 April 1904. Glasgow had the highest population density of any urban centre in Europe at that time. The parish of Govan alone had a population of over 100,000 in 1881 making it the fifth largest burgh in Scotland (Oakley, 1946). Premature deaths were not an uncommon occurrence, especially in the less well-off quarters (sadly they still are, if for different reasons). It has been said that nowhere in the Victorian world was the gulf between the 'haves' and 'have-nots' so pronounced as in Glasgow (McCarroll, undated). Late the following year, at the age of 40 years, on 29 December 1905, at 2 Nithsdale Drive, Alexander re-married one Isabella Wilson Robertson, a spinster ten years his junior. Doubtless one consideration would have been concern for his little daughters from his first marriage (Catriona MacKinnon Patience, born 1 February 1899; Dorothy Janette Patience, born 18 August 1901). On the certificate for his second marriage (issued from the district of Tradeston), Alexander's rank is given as 'mercantile cashier' of 342 Cumbernauld Rd, Glasgow. Another daughter, Margaret Robertson Patience, was born into this second marriage on 2 April 1912.

Alexander Patience (styled ultimately as a property valuator) died, aged 89 years, on New Year's day, 1 January 1954, from myocarditis; one of the degenerative diseases of old age (oddly his death registration details give his age as 88). No trace of any testament of his has come to light for the years 1954-56 in the Calendar of Confirmations and Inventories in the National Archives of Scotland (Fotheringham, pers. comm. to PGM). It could be that he died without leaving any testamentary papers (which seems surprising for one in commerce). His burial / cremation record has not been traced yet either. His wife died six months later (on 10 June 1954), aged 78 years, also from the same heart condition. She was living at that time at 40 Whitehall St, Finnieston (property now demolished, although a stub of road remains) overlooking the Broomielaw on the north bank of the Clyde.

Alexander Patience had occupied several addresses in Glasgow [2 Golfhill Terrace (Firpark St, Dennistoun); 39 Finlay Drive, Dennistoun; 342 Dennistoun Gardens, Cumbernauld Rd; 17

Kirkwood St, Ibrox (Ann. Rept Millport Marine Station, 1902; Hancock, 1992; Jean McMillan, pers. comm. to PGM)] over a comparatively short timespan in the early 1900s, suggesting that these might have been rented apartments. It may be pertinent to recall that 18% of Glasgow's million-plus population still lived in single rooms in 1891 (Treble, 1979). As has been remarked by Fraser & Maver (1996), locally, people tended to move up and down the housing scale but within a relatively restrained choice of areas. Apartments were typically rented on an annual basis (Fraser & Maver, 1996). Patience's job would certainly have facilitated apartment swapping and might explain why latterly his address tended to be given as care of his employers (the property and insurance agents and valuators [sic] Wm Metcalfe & Sons, 140 London St, Glasgow), in the Parkhead area near the Saltmarket [note: London Street became London Road in the mid-twentieth century, also incorporating Great Hamilton St and Canning St (Rachel Taylor, pers. comm. to PGM)]. One of Thomas Annan's famous photographs of Victorian Glasgow in MeCarroll's book (undated, p.34) provides a contemporary impression of that vieinity. As an aside, it is interesting to note the mutual frustrations regarding accuracy of their addresses that surface in the early (1907) Patience – Calman correspondence in the Natural History Museum [BM(NH) DF252/5] archives.

In Glasgow, between the mid-1880s and the mid-1900s, the economic fortunes of the skilled and 'upper stratum of the unskilled' had undergone a profound transformation for the better (Treble, 1979). Opportunities to better oneself clearly presented themselves, after a lengthy period of falling prices and increasing affluence generally (Cole & Postgate, 1963). Alexander Patience joined the Natural History Society of Glasgow, aged 33 years, on 28 March 1899 (Gibson, pers. comm. to PGM; Mitchell library archives, TD 1408/9/4/1) and the last time his name appears in their membership list is in 1930 (Hancock, 1992). During this interval he served on its Council, beginning 24 October 1905 (he was re-elected to its Council on 26 October 1909). His name is not included, however, in its List of Members published in 1946 (Gibson, pers. comm. to PGM). He appears not to have been a member of the Microscopical Society of Glasgow but he was a corresponding member of the Buteshire Natural History Society (Jean McMillan, pers. comm. to PGM) from 1910-1945 (*cf.* Hancock, 1992). In its early years, that Society was presided over by its co-founder, Dr John Nairn Marshall (1860-1945; the father of the late Dr Sheina M. Marshall, O.B.E., D.Sc., F.R.S. of Millport Marine Station fame) (Anon., 1945a; Munro, 1973; Russell, 1978). According to the Minutes of the Buteshire Natural History Society for 3 April 1907, Dr J. Marshall – a much loved local general practitioner in Rothesay and surgeon of the 'old school' (Russell, 1978), who was one of the best known medical practitioners in the West of Scotland (Anon., 1945b) - reported (from the Chair) that

Dr James Gemmill had agreed to give a lecture on 5th current, but had afterwards to cancel the engagement on account of indisposition. Mr Alexander Patience, Glasgow, was then asked to take Dr Gemmill's place and had agreed to do so, his subject being 'The depths of the sea', with lantern illustrations.

Their Minutes of 15 May 1907 report that: the lecture on 'The Depths of the Sea' with lantern illustrations, referred to in the last Minute had been given by Mr Alexander Patience to a good audience of members and friends in the Rothesay Academy on that date [5th inst.], and the thanks of the Society were accorded to Mr Patience for a most interesting lecture."

Several reprints of Patience's papers, mostly on isopods, that now reside in the Millport Marine Station's (now U.M.B.S.M.'s) reprint collection are inscribed (one in particular; Fig. 1) in a beautiful hand, as would befit a clerk; 'Dr J. Marshall with the author's kind regards'. We know that J. N. Marshall had been a medical student in Glasgow University in 1882 (Glasgow University archives; DC276), he graduated M.B., C.M. that year and M.D. in 1885 (Anon., 1945b), so the two men were much of an age. Patience's links with Marshall would seem to have been close, since Patience noted taking *Trichoniscus albidus* 'in Dr Marshall's garden at [7] Battery Place, Rothesay' (Patience, 1908c). It is a great pity, therefore that we never had any occasion to ask Sheina Marshall for any memories she might have had about Patience before she died in 1977. In two of his *Trichoniscus* papers (Patience, 1908a,b), he also refers to 'my friend Mr R. S. Bagnall, F.E.S., Winlaton-on-Tyne'. Another amateur naturalist (he worked in his family's iron-forging and chain making business) - though primarily an entomologist (Dunn, 1983) - Richard Bagnall was also an established authority on woodlice and named the woodlouse *Philoscia patiencei* after our subject [now *Chaetophiloscia patiencei* (Bagnall, 1908)]. The only species of woodlouse in the currently recognised British list that was described by Patience is one of the pygmy woodlice, *Trichoniscoides sarsi* Patience, 1908 (Hopkin, 1991), his other species, e.g. *Cordioniscus spinosus* (Patience, 1907) and *Styloniscus stebbingi* (Patience, 1907) (see Hancock, 1992), being non-British species found only in hothouses (see also Vandel, 1960-62). In an earlier paper describing *S. stebbingi* (as *Trichoniscus*), Patience refers to taking the species in the greenhouse of another of his friends, the botanist 'Mr Peter Ewing, F.L.S. at Uddingston, Lanarkshire' (Patience, 1907b). A copy of Peter Ewing's compilation '*Glasgow catalogue of native and established plants*' (1899) was donated to Glasgow University by Patience. That volume now resides in the Special Collections section of the University Library along with Patience's copy of L. A. G. Bosc's *Manuel de l'Histoire naturelle des Crustacés* (1830).

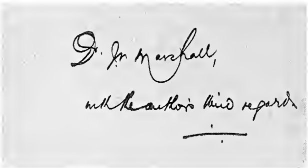
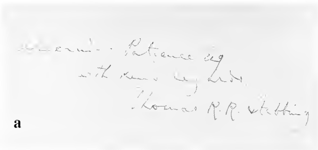


Fig. 1. From the front cover of a reprint of Alexander Patience's paper (1908c) on *Trichoniscus albidus* dedicated, in the author's handwriting, to his friend Dr J. N. Marshall (U. M. B. S. Millport reprint collection; ex-Buteshire Natural History Society).



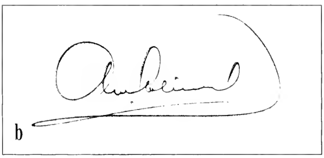


Fig. 2. a) The dedication to Patience on a reprint of Stebbing's paper on *Urothoe* (Stebbing, 1891) currently in the reprint collection at U. M. B. S. Millport; b) Alexander Patience's signature on a type-written letter to W. T. Calman, dated 17th April 1916 [BM(NH) DF252/13].

Although born a Victorian, Patience's contribution to carcinology took place mainly during the Edwardian era. He published a clutch of papers during the first decade of the 1900s, predominantly on carcinology but including one paper on fish (see Bibliography below); then his publication stream abruptly stopped. In 1910, one of his last contributions was even entitled 'Carcinological notes–1' although, as far as we are aware, no more papers in that series ensued [perhaps finding the crab *Xantho couchii* (now *Medaeus couchi*) 'snugly ensconced in an old boot' proved to have no sequel]. Thomas Scott, with whom he was working in 1902 (Patience & Scott, 1902; having received jointly ten shillings from the British Association for an investigation of Crustacea in the northern Clyde lochs), made no allusion to Patience as an authority on Crustacea in his own contribution on land, fresh-water and marine Crustacea published in the Handbook of the British Association for the Advancement of Science Glasgow meeting for 1901 (Scott, 1901). This supports the idea that Patience was just embarking on his carcinological interests at that date. Indeed, his name first surfaces in the Annual Reports of the Millport Marine Biological Station in 1897. There he is referred to as a 'Science Student, Glasgow' [at 32 years old, a mature student in modern parlance] whose subject was zoology, occupying a table at Millport in July of that year (table occupancy then cost 10s 6d a week; a not inconsiderable sum when it is recalled that apartments in Glasgow could be rented annually for under £10; see Fraser & Maver, 1996). It is interesting to note that even in the University there was no Faculty of Science in existence until 1893 (Mackie, 1954). Whether Patience had been encouraged in his crustaceology by David Robertson, 'the Cumbrae naturalist', is not known (Robertson died at the end of November 1896). Patience's occupation of a table at Millport became an irregular occurrence subsequently (presumably as circumstances allowed). He returned in 1898 (studying echinoderms). In 1901, he visited Millport twice (April, July) and, by then, he was studying Crustacea (and fishes on the second visit). That year too he reportedly donated a chart of the Clyde to the Marine Station. Obviously, his qualities became rapidly recognised since he was elected in March 1902 to the Committee of the Marine Biological Association of the West of Scotland, the body which ran the Millport Marine Station post-1900 (it is unclear though when his standing in that capacity expired).

In 1902, he is reported as being granted a week's use of S.Y. *Mermaid* for 'his British Association research' on Clyde Crustacea. This is intriguing. For thirty-odd years from the late 1830s, dredging survey work had been supported by the British Association for the Advancement of Science (B.A.A.S.) through its Dredging Committee. By the 1870s, however, the earlier enthusiasm had waned (funds had never been adequate, certainly not in the Clyde; see Miles, 1856) and after 1881 the Dredging Committee is never again mentioned in the Association's published reports (Rice & Wilson, 1980). Patience's involvement (together with Thomas Scott; see Patience & Scott, 1902) with 'British Association work' as late as 1902 is, therefore, noteworthy. Was this some local initiative as a result of the 1901 meeting in Glasgow? His name does not appear among the membership of the B.A.A.S. as listed in their

Glasgow volume of 1901, so perhaps his scientific ambitions remained rather constrained and circumscribed, i.e. despite his receiving some financial support (ten shillings) from that body for fieldwork the following year; perhaps further evidence of restricted resources (see below)?

Shortly thereafter, Thomas Scott (1904) was writing about entomostracans that he had 'obtained in some tow-gatherings submitted to me for examination by my friend, Mr Alexander Patience, of Glasgow'. April 1904 witnessed the personal tragedy of the death of his first wife but Patience was working on Crustacea at Millport again in April 1905, i.e. before he re-married. Such single weeks of indulgence as a marine naturalist would presumably have swallowed up much of his summer holiday allowance [taken in Prestwick in 1912]. As he reminded Calman in August of 1912, 'you know I am a busy commercial man and for long stretches the only time I have is that between Saturday and Monday' [BM(NH) DF252/9]. Earlier, on 24 May 1907, Patience has written to Calman [BM(NH) DF252/5] "I have been away to the seaside alas, not on biological research but in consequence of the illness of one of my little girls, who has suffered much with whooping cough. … I regret I had not the pleasure of seeing you when you were last at Millport. I made an effort to go, but was prevented at the last moment. Pace told me you were then studying the Cumacea. I could have directed your steps…."

We may presume from the fact that he is not recorded as having made any donations to the Millport Marine Station until 1906 (one guinea), or indeed to have paid a subscription as a member of the Association until 1907 (he did not keep that up for long either. His name lapsed from the membership list in 1908) that he was, indeed, not well-off financially (see below). He led an excursion from the Natural History Society of Glasgow to Millport on 19 August 1905. He was noted again as working at Millport, this time on Amphipoda, on 18 September 1909 (with a Mr A. Scrymgeour).

Clearly overcoming any logistical constraints, he soon established himself sufficiently to be in correspondence with some of the great names of Victorian and Edwardian carcinology. There are several reprints, now in the library at U.M.B.S. Millport (originally presented by Patience to the Zoology Laboratory, Glasgow University), of papers by T. R. R. Stebbing (Stebbing, 1887, 1891, 1913), that are inscribed 'Alexander Patience Esq., with kind regards, Thomas R. R. Stebbing' (Fig. 2a) and it was Stebbing who communicated Patience's paper 'On a new British terrestrial isopod' [which Patience had named *Trichoniscus stebbingi*] to the Linnean Society of London (Patience, 1907b). On 25 January 1907, Calman wrote to Patience from London reporting having listened to Stebbing give this paper 'with much interest' and requesting co-types for the Natural History Museum's collections [BM(NH) DF252/5]. Patience also acknowledged his indebtedness to that other giant of Victorian carcinology, Canon A. M. Norman, F.R.S., for assistance and advice over the contents of his paper on the amphipod *Dexamine thea* (Patience, 1908a). Recall that Norman was the man whom E. Ray Lancaster had called 'the greatest naturalist dredger of his day' (Davis, 1983). We may infer from his text that Patience had corresponded with A. O. Walker over his contribution on *Phoxocephalus* (Patience, 1909a). However, his conclusion that Scott's *P. fultoni* was the juvenile form of Walker's *P. pectinatus* is now discredited [Calman's reply to Patience in 1909 had been explicit in saying that 'it will require some very strong evidence to make me believe that *P. fultoni* is the immature stage of anything else!]. *Metaphoxus fultoni* (Scott) is recognised as distinct from *M. pectinatus* (Walker) (see Lincoln, 1979) and their (Walker's, Norman's, Patience's) protestations against *Metaphoxus* as a construct, did indeed fall to Stebbing's recognition of the genus. But whether or not Patience's follow-on comment (29 October 1909) to Calman regarding this issue that 'if I find myself wrong I shall ask for absolution on bended knees' [BM(NH) DF252/7] ever resulted in the promised geniculation is not recorded. Patience seems too to have had direct personal contact with Stanley W. Kemp (see below also), then of the Irish Fishery Board in Dublin, to whom he 'showed' material of the shrimp *Philocheras bispinosus* (see Patience, 1906b). Kemp was a leading authority on natant decapods (Hardy, 1946). In one of his later letters to Calman (14 February 1916), Patience drops another famous name when he says 'through the courtesy of Professor D'Arcy Thomson, I had the privilege recently of examining a few crabs from the Dundee Museum' [BM(NH) DF252/13]. He was in correspondence with E. L. Bouvier and Edouard Chevreux in France as well. So, all in all, he was becoming well connected (and on increasingly familiar terms) with the crustacean authorities of his day. His correspondence with Calman, which began stiffly in 1907, 'Dear Dr Calman' reflected this burgeoning confidence. By 1917, it had become the less formal 'My dear Calman'.

There are twenty-five letters, all but one of Patience's being hand-written, in the extant correspondence between Patience and Calman archived at the Natural History Museum in London (some of his written on Metcalfe & Sons headed notepaper) between 1907 and 1917 [BM(NH) DF 252/5,7,9,13], together with a pen sketch comparing two crabs. The letters mostly relate to deposition of material of his new species of woodlice and amphipods, or seek advice concerning identifications of amphipods and decapods. They also reveal some useful personal insights. Financial strictures probably dictated that Calman's professional advice [BM(NH) DF 252/7] that 'you would find a fortnight's visit to London would enable you to make more progress than many

months of work at home' was never actually realisable.

The fact that there are several 'heavyweight' taxonomic monographs, on a diversity of crustacean taxa from far-flung places (Faxon, 1895; Alcock, 1905, 1906; Brian, 1906; Chevreux, 1906, 1912; Walker, 1907), that once belonged to Patience and that he had originally presented to the Zoology Department in Glasgow University (all now held in the main University library) certainly suggests that he had credible pretensions to becoming a serious crustacean taxonomist, with horizons wider than the Clyde. Additionally, there are several references in the *Proceedings of the Natural History Society of Glasgow* to his exhibiting crustacean collections to the membership. These not only included Clyde material (24 June and 28 October 1902) but also two species of crabs collected from New Zealand by a Mr Dunlop (26 March 1907) and some Crustacea from the Merqui Archipelago and East Portuguese Africa which he had received from the University of Aberdeen for examination (30 March 1909). He remonstrated with Calman, however, that the Indian Museum had 'a stronger claim to the Merqui material' (note De Man, 1887) when Calman clearly wished for some of it to be retained in London [BM(NH) DF252/13]. In his letter to Calman [BM(NH) DF 252/7], dated September 1909, he bemoaned the fact that:

"Our scientific libraries in Scotland are very poorly furnished with carcinological literature. Probably at the present moment, I am better furnished in this respect than of them all combined if I can take the Glasgow University as an example. I have bought *fairly extensively* from Friedländer recently *but as I am a poor man I must beg as much as I can* [our italics, his underlining], so I shall be glad always of any copies in our line you can send me".

Noting these problems, Calman had replied to Patience 'you are a brave man to try to work out a collection of tropical Crustacea with libraries as ill furnished as those of Glasgow seem to be!'. The 'Friedländer' referred to in the above quotation would have been the famous German bookselling firm of B. Friedländer & Sohn, Karistrasse 11, Berlin N.W. There is a reprint of a paper by Chevreux & Bouvier (1893) in the U.M.B.S.M. collection bearing on its cover both the rubber-stamped name 'ALEXANDER PATIENCE' as well as that firm's oval ink stamp. So, in spite of pleading poverty, Patience was clearly acquiring some of the reference works that he needed on the open market internationally.

Significantly, the monographs which Patience donated to Glasgow University all emanate from the turn and first decade of the twentieth century. All the more surprising, therefore, in light of the enthusiasm he had expressed only two years previously, that he disappears abruptly from view as a publishing carcinologist after 1911 (aged only 46 years) - just when he was beginning to make a name for himself (Brian had inscribed his beautifully illustrated monograph on parasitic copepods '*A Monsieur Alex. Patience en hommage, Alexandre Brian, 26.II.10*') - especially considering that he lived-on for another 43 years. His researches did continue for a while thereafter but his publication stream dried-up (see below). It looks as if he donated his library to the University of Glasgow when he decided to abandon active crustaceology. Sadly, his contributions on woodlice came just too late to achieve recognition by Webb & Sillem (1906) in their contemporary monograph on the British species. Such an abrupt termination to a decadal-long contribution is reminiscent of a famous Dutch biologist from an earlier era, the Amsterdamer Jan J. Swammerdam (1637-1680); though whether or not religious fanaticism extinguished Patience's activity as well (*cf.* Miall, 1934), we may never know. But there are other possible explanations.

Apparently, Huntington's chorea (first recognised in 1872) is associated with the Patience family in Avoch (and Lincolnshire) (Jane Patience, pers. comm. to PGM). This cruel inherited degenerative disease, caused by a mutation on chromosome 4, usually strikes between the ages of 35-40 years and typically results in death 10-20 years later (the folk-singer Woody Guthrie suffered its ravages in our generation). The last mention of Patience's activity in the scientific literature, of which we are aware, is in 1936; when he communicated an address (Patience, 1936) on James Murray (oceanographer on Vilhjalmur Stefansson's 1913-18 Arctic expedition) who had joined the Andersonian Naturalists' Society in 1896. Patience's address, however, was presented on his behalf (perhaps significantly?) to the Natural History Society of Glasgow (the Andersonian's successor) by Professor L. A. L. King. Sadly, it was never published. He would have been about 71 years old then. Could it be that Alexander Patience was a sufferer and that at the onset of symptoms he gave up active participation in natural history? The involuntary movements and increasing mental confusion associated with this disease would certainly make dissecting small crustaceans and doing complex taxonomy progressively more difficult. Against that proposition, however, he did live on to a ripe old age, just attaining 89 years (dying from degeneration of the heart). There is no mention of Huntington's chorea as a cause of death in Alexander's particular lineage, so far as is known (Alexandra Norton, pers. comm. to PGM). Equally, there is no sign of any involuntary movements in his handwriting, to 1916 anyway; his signature at that time still being accomplished with an assured flourish (Fig. 2b).

Alternatively, had he simply fallen out with the Millport Marine Station's then Director, Mr Stephen Pace (1872-1941), a man who 'disliked amateurs' (Marshall, 1987)? Pace, however, resigned in 1907 to be replaced by the reassuringly 'amateur-friendly' Richard Elmhirst (King, 1953). Elmhirst (1884-1948) was certainly a young man

whom Patience must have liked since he named his new amphipod, *Isaea elmhirsti* Patience, 1909, for him (Patience, 1909b,c). Regarding Millport's problems, MacBride had written that 'the single root of all the trouble was Pace' (Marshall, 1987). Pace or no Pace, Patience made extensive dredging excursions on S.Y. *Mermaid* from Millport during the summers of 1906 and 1907 (see Patience, 1906b), i.e. the years of his Millport donation and subscription (see above). Presumably, he had felt duty-bound to proffer some contribution in return for services rendered. He is, however, noted - just once - in the interval between 1913-1930 (in 1925-26) as subscribing (another guinea) to the Scottish Marine Biological Association (as the organisation running the Millport Marine Station had by then become). In his 1906b paper, he notes that:

"since the "Mermaid" was put into commission I have been able at different times to carry out investigations on the distribution of the *Malacostraca* on systematic lines." These investigations extended from the Gareloch to the southern boundary of the Clyde Sea area, including all the principal lochs and a considerable part of the Barrier Plateau, dredging being carried out in depths down to 107 fathoms

He utilised other opportunities too, sampling from J. Rennie's yacht '*Hilda*' in Lamlash Bay, Arran during the summer of 1906 (Patience, 1909a). The year 1906 was a year of disasters at Millport, when the Marine Station entered into an unhappy period of difficulties and decline (Marshall, 1987). Sheina Marshall reported that the *Mermaid* was laid-up all year in 1906 as a cost-saving measure. So perhaps this was why he turned to the *Hilda*? The period 1907-1910 was generally one of slump in the heavy engineering and shipbuilding industries on the Clyde and doubtless its devastating effect on the local economy (Treble, 1979) rippled through all strata of society in the area (Dow & Kinniburgh, 1962; Fraser & Maver, 1996). In Patience's Crangonidae paper (1906b), he describes having sampled 720 stations in the Firth of Clyde - a huge amount of work (presumably accomplished over some considerable length of time). He reported "hoping shortly, to place the complete record, not only of these observations, but also of those had made for some years prior to the advent of the *Mermaid*, in the hands of the Recorder in the Natural History Department of Glasgow University, where they will be available for the use of marine zoologists". Professor [later Sir] John Graham Kerr, F.R.S., holder of the prestigious Regius Chair of Zoology at Glasgow University between 1903-1935, was one of the main 'professional' protagonists in the Millport controversy alluded to below (Marshall, 1987). His Department, of course, was the recipient of Patience's largesse *vis-à-vis* his reference works, which hardly suggests that they were at loggerheads. Indeed, we know that Graham Kerr had a high regard for Patience's friend, Dr J. N. Marshall, who was also a keen amateur naturalist (Kerr, 1922). Between 1908 and 1910, Patience indeed presented a significant number of crustacean specimens to the University, numbering in excess of 230 lots. Each one is catalogued by Patience himself (and usually signed up the right-hand margin) on pre-printed cards. His identifications were sometimes verified by other specialists (including T. Scott, A. M. Norman, D. M. Reid). That card index is held in the Patience Collection in the Zoology Museum (University of Glasgow). The cards are headed 'Glasgow University – Local Fauna Catalogue' and carry some general observations as well as specific information on each preserved sample. It is possible that among these is the physical expression of Patience's intention to deposit details of Clyde dredging data. If so, then they are not as detailed as he promised and do not allow direct historical comparison with modern results. Sadly, whether Patience ever made his extensive disposition of raw data remains unclear. The whereabouts of such a potentially extremely useful historical database of local marine biological information thus remains presently unknown. We would plead that anybody knowing anything about the present whereabouts of Patience's files (which were likely to have been kept meticulously; he being a book-keeper by profession) contacts one or other of the present authors.

James Chumley acknowledged Patience's help in scrutinising his listing of Crustacea in his own *Fauna of the Clyde Sea area; being an attempt to record the zoological results obtained by the late Sir John Murray and his assistants on board the S. Y.* "Medusa" *during the years 1884 to 1892* (Chumley, 1918). Patience's missing data set would, theoretically, follow-on nicely from that treatment. Interestingly, Stephen Pace had made plans for an extensive biological survey of the Clyde Sea area, which he and his assistants (for he meant to appoint several) were to undertake. It was calculated by the 'popular' side, i.e. of the 'popular' *vs* 'professional' warring parties then struggling for ascendancy over the affairs of the Marine Station at Millport, that such a survey would cost £1,000 and occupy the full time of the staff (Marshall, 1987). One presumes that this amateur coterie would have included Patience (had he been quietly slid off the Millport Marine Station's Committee for being 'only' an amateur?). Pace's departure in 1907, after his resignation had been called for in the July, put paid to such a notional survey especially after a badly worded resolution was passed at the Annual General Meeting in March 1907 stating that 'this meeting did not approve of the staff being employed in biological survey' (Marshall, 1987). Was Patience's information intended as a counter-blast to the professionals, to show what amateurs could do with minimal resources? At present, we can only speculate. His comment, however, that 'it is a pity that advantage was not more fully taken of the opportunities presented by the once fully-equipped steam-yacht "Mermaid"' (Patience,

1910), could easily be interpreted as a 'dig' in that direction.

Poignantly, among Patience's later extant exchanges with Calman from 1916 are patriotic and optimistic thoughts about their not being of an age called upon to fight in the First World War; thus we find the following (Patience to Calman [BM(NH) DF 252/13]), written in March, i.e. only a few weeks before the dreadful carnage that initiated the Battle of the Somme:

"I am like yourself unfortunately in 'a group' which may not be called up for a considerable time. We are probably on the eve of great events and [illegible word] earnestly trust we are going forward to final victory".

Another letter to Calman, dated a few weeks later (17 April 1916), spoke of his 'staying at Millport with my wife and family until the end of this month', which sounds as if he might still have been combining marine biology with family holidays to that date anyway [BM(NH) DF252/13]. In 1914 and onwards into the early post-war [WWI] years, the Marine Station at Millport was 'pitifully handicapped by financial strain' (Anon., 1939). The forced sale of the S.Y. *Mermaid* in 1915 meant that, for some years, dredging and collecting from Millport had to be done from rowing boats; curtailing the opportunities for doing effective offshore work (until 1922 and the arrival of the *Nautilus*; see Marshall, 1987). This might have some bearing on why Elmhirst's book from that difficult era related only to shore life (Elmhirst, 1913).

Paradoxically, in spite of his published output lapsing, Patience was still preparing to spread his wings taxonomically in 1917. Perhaps understandably, in light of the above, he was then concentrating on preserved material from collections donated from overseas. In a subsequent letter to Calman, dated 2 August of that year [BM(NH) DF252/9], he says that he is

"getting on pretty well with my Burma and East African collection. I have completed my paper on the Stomatopoda, but as my friend Stanley Kemp is preparing a paper on the Indo-Pacific species, I have sent him as requested my M/S as he got to know I had Simpson's material. I trust however it will be published very shortly" [it never was; what happened to it is another mystery].

Kemp, of course, had himself once worked for the Indian Museum continuing Alcock's work on the decapod Crustacea (Hardy, 1946). Patience was also, in that same letter, angling vigorously for Calman to obtain him a copy of the '*Alert*' Crustacea report ('I require it constantly at my elbow') which had been published by the Trustees of the British Museum (see Miers, 1884); a favour with which Calman could not oblige him. Calman explained that copies had been few, the Crustacea sections had not been issued separately and the whole report had only been sent out to institutions (including Glasgow University), not to private individuals. Yet Patience claimed that the University library did not possess a copy. Was he being 'economical with the actualité' in trying to engineer himself a more convenient personal copy? A copy certainly resides in the University library today. Whatever the truth of the matter, Patience was obviously still thinking strategically about crustacean taxonomy, and on a global scale, in 1916/17 (when in his early fifties). But his international take-off never materialised. Why did he give it all up, just when he was about to step beyond the threshold of the parochial? Had Kemp been destructively critical of his efforts? Such a suggestion would seem out of character for such a well-loved, modest man as Kemp (see Hardy, 1946) whom Patience counted as his friend. Unfortunately, the National Marine Biological Library at Plymouth contains no correspondence from this date in their Kemp archive (Emma Woodason, pers. comm. to PGM), i.e. that might shed any light on this issue. So who, or what, extinguished his rising ambition remains a mystery. Patently, the arrival of his third daughter during his middle age (in 1912), cannot be seen as the agency that applied the brake to his enthusiasm for carcinology.

The Clyde Card Catalogue Committee was created by the University of Glasgow, leading up to the British Association meeting at Glasgow in 1928, to generate and maintain a card catalogue of the flora and fauna of the Clyde area (Weddle, 2001). The scheme was disbanded in 1957; the catalogue being transferred to the Kelvingrove Museum in the 1980s (Hancock, 1992), from whence it was recently moved to Glasgow City Museums Resource Centre. There are 21 cards made out by Patience but the information on them is sketchy. The majority of them just record a species name and location. Only a few have dates and depths (M. Rutherford, pers. comm. to EGH).

Amateurs have, of course, contributed hugely to our knowledge of natural history and systematics (including of the Crustacea). Thus a Danish contemporary of Patience's, Gustav Budde-Lund (1846-1911) who, in spite of failing to obtain a Master's degree in zoology (Jeppesen, 2000), became a world authority on terrestrial isopods, was a businessman who owned a brush factory (Wolff, 1993). Sadly, for we can safely assume that Patience would have been in contact with him, there is no known repository of Budde-Lund correspondence, certainly not in the Copenhagen Museum (T. Wolff, pers. comm. to PGM). Patience himself paid tribute in the Society's *Proceedings* (28 January 1908) to the scientific attainments of another amateur, Dr Alexander Frew, one of the Ordinary members of the Natural History Society of Glasgow, who died that year, who had contributed much to the knowledge of West of Scotland Mollusca. Whilst Miall (1934) may have had little time for aimless amateurism in Victorian and Edwardian natural history (see also Baker & Bayliss, 1985), focused contributions by *amateurs* - doing what they do for the love of it

alone – can only be applauded. They have helped to put us where we are today. One such unmedalled volunteer [note BM(NH) DF252/7] was Alexander Patience of Glasgow.

ACKNOWLEDGEMENTS

We are grateful to the following persons for their kindness and assistance: Ms Jean McMillan (Archivist, Rothesay Museum), Ms Rachel Taylor (Archivist, Mitchell Library, Glasgow), Mr Mike Rutherford (Glasgow City Museums), Mr Lewie and Mrs Jane Patience (Avoch Heritage), Mrs Alexandra Norton (Peebles), Dr Jack Gibson (Scottish Natural History Library, Kilbarchan), Ms Karen Taylor (Archives; Natural History Museum, London), Mr Robert Fotheringham (National Archives of Scotland), Mrs Emma Woodason (Library, MBA, Plymouth) and Dr Torben Wolff (Copenhagen Museum). Mr Steve Parker is thanked for digitising the Figures.

BIBLIOGRAPHY OF ALEXANDER PATIENCE'S PUBLISHED WORKS

Note 1: there are neither personal papers of Patience's in the archival material relating to the Glasgow Natural History Society held in Glasgow's Mitchell Library archives (ref. TD 1408), nor any material related to the firm of Metcalfe & Son in their commercial archives.

Note 2: his scientific papers have been quoted elsewhere under a variety of dates: *viz.* dates read, dates published, dates reprints issued. Several years sometimes elapsed between these events. The papers are listed below according to their earliest dates, to better reflect the timing of AP's activity but fullest possible chronological details are presented for cross-referencing.

Note 3: some of the references below are not strictly titles of papers but relate to reports of his activities in the quoted documentation.

Patience, A (1900 /1901). On the decapod Crustacea of the Largs Channel. *Communications of the Millport Marine Biological Station*, 1, 25-31.

Patience, A (1902a). Crustacea from Loch Fyne. *Transactions of the Natural History Society of Glasgow*, 6 (n.s.), 386-387.

Patience, A (1902b). Exhibit of some higher Crustacea from the Firth of Clyde; with remarks on the phenomena of commensalism, parasitism, and 'masking'. *Transactions of the Natural History Society of Glasgow*, 6 (n.s.), 270-271.

Patience, A (1903a). On the occurrence of the schizopod *Pseudomma roseum* G. O. Sars, within the Clyde Sea area. *Transactions of the Natural History Society of Glasgow*, 7 (n.s.), 74-76. [read 25 Aug. 1903, published 1907]

Patience, A (1903b). Note on the occurrence of the schizopod, *Macropsis slabberi* (van Benenden), within the Clyde Sea area. *Transactions of the Natural History Society of Glasgow*, 7 (n.s.), p.110 only [published 1907].

Patience, A (1903c). Report on the Crustacea collected during the dredging cruise of the Millport Marine Biological Association's steamer 'Mermaid' since May 1902. *Report of the seventy-third meeting of the British Association for the Advancement of Science*, Southport, 1903, 308-310. [published 1904]

Patience, A (1906a). On the occurrence of *Idothea neglecta*, G. O. Sars, and *Idothea viridis* (Slabber) within the Clyde Sea area, and some notes on other Clyde species of *Idothea*. *Transactions of the Natural History Society of Glasgow*, 8 (n.s.), 42-46. [read 26 September 1905, reprints issued 1908, published 1911]

Patience, A (1906b). Some notes on the distribution of the Clyde Crangonidae. *Transactions of the Natural History Society of Glasgow*, 8 (n.s.), 64-71. [read 20 April 1906, reprints issued 1908, published 1911]

Patience, A (1906c). On the occurrence of *Gobius orca* Collett within the Clyde Sea area. *Transactions of the Natural History Society of Glasgow*, 8 (n.s.), 74-76. [read 29 May 1906 by Mr Alexander Ross in the absence of Mr Patience, see *TNHSG*, 8, p. 110; reprints issued 1908, published 1911] – Note: this species is now *Lebetus orca* (Collett, 1874)

Patience, A (1906d). On some terrestrial isopods new to the Clyde faunal area, and some notes on the distribution of the rarer species. *Transactions of the Natural History Society of Glasgow*, 8 (n.s.), 80-86. [read 26 June 1906, reprints issued March 1908, published 1911]

Patience, A (1907a). On a new British terrestrial isopod. *Annals of Scottish Natural History*, 1907, 85-88, pl.iii. [preliminary description read to Glasgow Natural History Society, 28 January 1908]

Patience, A (1907b). On a new British terrestrial isopod. *Journal of the Linnean Society of London (Zoology)*, 30, 42-44, pl. 7.

Patience, A (1908a). Some notes concerning the male of *Dexamine thea*, Boeck. *Annals & Magazine of Natural History*, (Ser. 8), 1, 117-122, pl.v.

Patience, A (1908b). On a new British terrestrial isopod (*Trichoniscus linearis* sp. n.). *Annals & Magazine of Natural History*, (Ser.8), 1, 280-282, pl. xi. [now *Miktoniscus linearis*]

Patience, A (1908c). On *Trichoniscoides albidus* (Budde-Lund) and *T. sarsi* Patience (nom. nov.). *Annals & Magazine of Natural History*, (Ser. 8), 2, 84-88, pl.vi.

Patience, A (1909a). On the genus *Phoxocephalus*. *Glasgow Naturalist*, 1, 116-134, pls iii-iv. [read 23 February 1909]*

Patience, A (1909b). Preliminary description on a new British amphipod, *Isaea elmhirsti* sp. n. *Glasgow Naturalist*, 1, 134-135.

Patience, A (1909c). On a new British marine amphipod. *Glasgow Naturalist*, 2, 16-19, pls I & II. [read 26 October 1909, published 1910]

Patience, A (1910). Carcinological notes.- I. *Transactions of the Buteshire Natural History Society*, 3, 69-79, pls 1 & 2.

Patience, A (1911). Paper read on *Trichoniscus linearis* and *Philoscia patiencei*, two new British species of terrestrial Isopoda. *Transactions of the Natural History Society of ow*, 8 (n.s.), 298. [read 28 January 1908]

Patience, A (1936). Report concerning an unpublished communication on James Murray. *Glasgow Naturalist*, 12, p. 105 only.

Patience, A & Scott, T (1902). Report on the crustacean fauna of the northern Clyde lochs. *Report of the seventy-second meeting of the British Association for the Advancement of Science, Belfast*, 1902, p. 272 only. [published 1903]

*[It may be noted *en passant* that six printer's blocks for Patience's *Phoxocephalus* paper (1909a) in *The Glasgow Naturalist* reside in The Natural History Society of Glasgow's repository within the Mitchell Library archives in Glasgow (ref. TD 1408/1/9/7)].

REFERENCES

Alcock, A (1905). *Catalogue of the Indian decapod Crustacea in the collection of the Indian Museum.* Part II. *Anomura,* fasc.1. *Pagurides.* Calcutta, Trustees of the Indian Museum, 197pp., pls I-XVI.

Alcock, A (1906). *Catalogue of the Indian decapod Crustacea in the collection of the Indian Museum.* Part III. *Macrura,* fasc.1. *The prawns of the Peneus group,* Calcutta, Trustees of the Indian Museum, 55pp., pls I-IX.

Annual Reports of the Marine Station at Millport (1897 - 1910)

Anonymous (1939). Marine biology in the Firth of Clyde. Semi-jubilee of the Scottish Marine Biological Association. *The Scottish Naturalist,* July-August 1939, pp. 89-93.

Anonymous (1945a). Dr J. N. Marshall. *Transactions of the Buteshire Natural History Society,* 13, 3-4.

Anonymous (1945b). Obituary: John Nairn Marshall, M.D., C.M., F.R.F.P.S.Glasg. *Glasgow Medical Journal,* 25, pp.101, 136-7.

Baker, RA & Bayliss, RA (1985). The amateur and professional scientist: a comment on Louis C. Miall (1842-1921). *Naturalist, Hull,* 110, 141-145.

Brian, A (1906). *Copepodi parassiti dei pesci d'Itallia.* Genova, Stab. Tipo-litografico R. Istitto Sordomuti, 187pp., pls I-XXI.

Chevreux, E (1906). Crustacés Amphipodes. *Expédition Antarctique Française (1903-1905) commandée par le Dr J. Charcot.* Masson et Cie, Paris, 1-100.

Chevreux, E (1912). Amphipodes. *Deuxième Expedition Antarctique Française (1908-1910) commandée par le Dr J. Charcot.* Masson et Cie, Paris, pp. 79-186.

Chevreux, E & Bouvier, EL (1893). Les amphipodes de Saint-Vaast-la-Hague. *Annales des Sciences Naturelles (Zoologie),* 15, 109-144, pl.2

Chumley, J (1918). *Fauna of the Clyde Sea area; being an attempt to record the zoological results obtained by the late Sir John Murray and his assistants on board the S.Y.* "Medusa" *during the years 1884 to 1892.* Glasgow University Press, Glasgow, 200pp.

Cole, GDH & Postgate, R (1963). *The common people 1746-1946.* Fourth edn, reprint. Methuen & Co. Ltd, London, 742pp.

Davidson, JDG (2003). *Scots and the sea.* Mainstream Publishing, Edinburgh, 256 pp.

Davis, P (1983). Marine biologists. Pp. 45-63 in Lunn, A.G. (editor) *A history of naturalists in North East England.* Department of Adult Education, University of Newcastle upon Tyne.

De Man, JG (1887). Report on the podophthalmous Crustacea of the Mergui Archipelago, collected for the Trustees of the Indian Museum, Calcutta by Dr. Anderson, F.R.S., Superintendent of the Museum. Part I. *Journal of the Linnean Society of London, Zoology,* 22 (136), 1-64.

Dow, JL & Kinniburgh, IAG (1962). The parish and burgh of Greenock. *The third statistical account of Scotland,* Collins, Glasgow, pp. 150-199.

Dunn, TC (1983). Mainly entomologists. Pp. 36-44 in Lunn, A.G. (editor) *A history of naturalists in North East England.* Department of Adult Education, University of Newcastle upon Tyne.

Ellis, J (1972). The changing tides of the River Clyde – 1750 to 1980. *Paper (No. 1374) delivered to Institution of Engineers and Shipbuilders in Scotland, 183 Bath St, Glasgow, 19th December 1972,* pp. 1-36.

Elmhirst, R (1913). *The naturalist at the sea-shore.* Adam & Charles Black, London, 86 pp.

Fraser, WH & Maver, I (Editors) (1996). *Glasgow.* Vol. II: *1830-1912.* Manchester University Press, Manchester, 532pp.

Hardy, AC (1946). Stanley Wells Kemp 1882-1945. *Journal of the Marine Biological Association of the United Kingdom,* 26, 219-234.

Hancock, EG (1992). Alexander Patience and his work on woodlice (Crustacea: Isopoda) in the Clyde area with a list of recorded species. *Glasgow Naturalist,* 22 (2), 133-139.

Hopkin, S (1991). A key to woodlice of Britain and Ireland. *Field Studies,* 7, 599-650.

Jeppesen, PC (2000). Catalogue of terrestrial isopod taxa and type material described by Gustav Budde-Lund (Crustacea: Isopoda). *Steenstrupia,* 25, 221-265.

Jones, NS (1976). *British Cumaceans.* Synopses of the British Fauna (new series), No. 7, The Linnean Society of London, London. 66pp.

Kerr, JG (1922). Popular lecture: zoology and sanitary science. *The Incorporated Sanitary Association of Scotland, forty-eighth Annual Congress, Rothesay, 1922,* pp. 1-17.

King, LAL (1953). Foreword. Pp. vi-vii in S. M. Marshall & A. P. Orr (editors) *Essays in marine biology: being the Richard Elmhirst memorial lectures.* Oliver & Boyd, Edinburgh.

Lincoln, RJ (1979). *British marine Amphipoda: Gammaridea.* British Museum (Natural History), London, 658 pp.

Mackie, JD (1954). *The University of Glasgow 1451-1951: a short history.* Jackson, Son & Company, Glasgow, 341pp.

McCarroll, J (undated). *Glasgow Victoriana: classic photographs of Thomas Annan.* Fort Publishing Ltd, Ayr, 64 pp.

Marshall, SM (1987). An account of the Marine Station at Millport. *Occasional Publication* No. 4, University Marine Biological Station, Millport, 133 pp.

Maver, I (2000). *Glasgow.* Edinburgh University Press, Edinburgh, 256 pp.

Miall, LC (1934). *Natural history of aquatic insects.* Macmillan, London, 395 pp.

Miers, EJ (1884). Crustacea. In, *Report on the zoological collections made in the Indo-Pacific Ocean during the voyage of H. M. S. Alert 1881-1882.* Part I. *The collections from Melanesia.* Part II. *The collections from western Indian Ocean.* British Museum (Natural History), London, pp. 178-322, 513-575, pls 18-32, 46-51.

Miles, CP (1856). Dredging report – Frith of Clyde. *Report of the British Association for the Advancement of Science,* 1856, Part 1, 47-53.

Munro, IS (1973). *Island of Bute.* David & Charles, Newton Abbot, 224 pp.

Nicolson, C (2004). The name game. *The Scots Magazine,* March 2004, 306-307.

Oakley, CA (1946). *The second city.* Blackie & Sons, London, 349pp.

Rice, AL & Wilson, JB (1980). The British Association Dredging Committee: a brief history. Pp. 373-385 in Sears, M. & Merriman, D. (editors) *Oceanography: the Past.* Springer-Verlag, New York.

Russell, FS (1978). Sheina Macalister Marshall 1896-1977. *Biographical Memoirs of Fellows of the Royal Society,* 24, 369-389.

Scott, T (1901). *Land, fresh-water, and marine Crustacea.* Pp. 328-358 in Elliot, G. F. S., Laurie, M. & Murdoch, J. B. (editors) *Fauna, flora & geology of the Clyde area.* British Association for the Advancement of Science, Glasgow.

Scott, T (1904). On some Entomostraca from the Gulf of St Lawrence. *Transactions of the Natural History Society of Glasgow*, 7 (n.s.), 46-52.
Stebbing, TRR (1887). On some new exotic Amphipoda from Singapore and New Zealand. *Transactions of the Zoological Society of London*, 12, 199-210, pls XXXVIII-XXXIX.
Stebbing, TRR (1891). On the genus *Urothoe* and a new genus *Urothoides*. *Transactions of the Zoological Society of London*, 13, 1-30, pls I-IV.
Stebbing, TRR (1913). On the Crustacea Isopoda of the 'Porcupine' Expedition. *Transactions of the Zoological Society of London*, 20, 231-246.
Treble, JH (1979). *Urban poverty in Britain 1830-1914*. Methuen, London, 216 pp.
Vandel, A (1960-62). Isopodes terrestres, première et deuxième parties. *Faune de France*, 64 & 66, pp. 416 & 514.
Walker, AO (1907). Crustacea III. Amphipoda. *National Antarctic Expedition, Natural History*, 3, 38pp, pls 1-13.
Webb, WM & Sillem, C (1906). *British woodlice, being a monograph of the terrestrial isopod Crustacea occurring in the British islands*. Duckworth & Co., London, 54pp., pls I-XV.
Weddle, RB (2001). The 'Clyde Cards': an account of biological recording in the West of Scotland. *Glasgow Naturalist*, 23, 88-99.
Wolff, T (1993). More than 200 years of crustacean research in Denmark. Pp. 207-223 in Truesdale, F. (editor) *History of carcinology*. A. A. Balkema, Rotterdam.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 131-132.

THE SPREAD OF KNOPPER GALL WASPS *(ANDRICUS QUERCUSCALICIS)* INTO THE CLYDE AREA

Norman & Pearl Tait
11 Rosshall Place, Renfrew, PA4 0BA.

ABSTRACT

The Knopper gall wasp (*Andricus quercuscalicis)* Burgsdorf 1783 (Hymenoptera: Cynipidae) has invaded western and northern Europe from southern and eastern Europe over the last 400 years. In the late 1950s the insect arrived in the south of England, presumably having crossed the English Channel on high altitude air currents, and has slowly spread northwards reaching southern Scotland in 1995. This species of gall wasp has an obligate sexual generation in springtime on Turkey oak *(Quercus cerris)* and an agamic generation in autumn on *Quercus robur*. The random distribution of Turkey oaks in Scotland will limit further northward expansion. This paper describes the Knopper gall wasp's advance into suitable sites in west and central Scotland.

LIFECYCLE

The complex lifecycle of the Knopper gall wasp *Andricus quercuscalicis* Burgsdorf 1783 (Hymenoptera: Cynipidae) involves an annual obligate alternation between two different oak tree hosts, one introduced to Britain and the other a native species.

In spring asexual females oviposit into the male flowers of the introduced Turkey oak *Quercus cerris,* (L.). The hatching larvae induce tiny, thin-walled, flask-shaped galls to develop on the catkins in April and May giving rise to a sexual generation. Males and females of the sexual generation emerge in late May to early June of the same year. The sexual females then oviposit into the female flowers of the native Pedunculate oak *Quercus robur* (L.) or occasionally Sessile oak *Q. petraea,* (L.) where an asexual or agamic generation develops, producing galls on the acorns in the summer and autumn (Stone, 1995). These large, 2cm galls are very conspicuous and consist of a mass of pyramidal-shaped, ridged tissue that breaks out between the cup and the acorn. Occasionally there are two, three or more growths on an individual acorn which completely cover it. The distinctive shape of these galls gave rise to the common name of 'knopper' from the German word *knoppe* meaning a kind of felt cap or helmet worn during the seventeenth century which the galls are said to resemble (Stone, pers. comm.). Russet-green, glabrous and sticky at first, the structures later become reddish coloured (front cover of this issue). After hardening the galls turn brown and drop to the ground in late autumn. Inside the gall is a single, large chamber with a small, hard, thin-walled, spherical inner structure at the base containing one larva. The asexual generation overwinters in the hard knopper galls. At the beginning of February the adult asexual female gall wasp (front cover of this issue) emerges through a vent at the top of the gall. These newly emerged insects later disperse to Turkey oak where the cycle is repeated.

The obligate generation on Turkey oak restricts the range of this invading species of *Andricus* in Britain to locations where both species of oak are to be found.

EXTENDED DISTRIBUTION OF TURKEY OAK AND THE SPREAD OF THE KNOPPER GALL WASP

The post-glacial native distribution of Turkey oak was originally restricted to south-eastern Europe and Turkey. In the last three to four hundred years Turkey oak has been planted extensively outside its native range and was first introduced to the British Isles in 1735. This, together with other non-native oak species, was planted in parks, gardens and country estates as an ornamental tree thus creating 'islands' of Turkey oak. It is now fairly widespread throughout most of the British Isles.

Following human dispersal of Turkey oak, *A. quercuscalicis* successfully invaded areas far from its native range of central and south-eastern Europe and Turkey. It reached Germany in 1631, arrived in the Netherlands about 1882 and has been known in the Channel Islands for at least a hundred years. The English Channel seems to have temporarily held up the Knopper gall wasp's invasion of mainland Britain, the first noted in Devonshire in the late 1950s. These arrivals were probably unassisted by human agency and would appear to have been air-borne. Adult gall wasps of different species have been found in samples taken in aerial currents at high altitudes. *A. quercuscalicis* has since spread steadily throughout England, Wales and parts of Ireland. The invasion front extended slowly northwards and by 1994 it was present at Alnwick, Northumberland on the east side of England and at north Lancashire to the west (Walker, pers. comm.).

SCOTTISH RECORDS

The first Scottish Knopper galls were collected in 1995 at Canonbie (35/396717) and later at Threave Gardens (25/684517) in Dumfries & Galloway region (Walker, pers. comm.). In 2001 Knopper galls were reported in the west of Scotland from Lanfine Estate, Newmilns in Ayrshire (Hancock, 2001) and in Gosford near Aberlady to the east (Muscott, 2001).

Table 1 lists Knopper gall observations made during September/October 2002, 2003 and 2004. From a small sample of 85 specimens collected at Mar Hall Hotel parkland, Renfrewshire in 2002, 21 identical insects emerged in late January and early February 2003. These were positively identified as asexual female Knopper gall wasps by E.G. Hancock, Glasgow University. The galls were retained for many months after the last gall wasp

emerged. Inquilines and parasitoids specific to the invading knopper galls are presently being studied as models for population dynamics. No inquilines or parasitoides associated with *A. quercuscalicis* appeared from the samples collected.

DISCUSSION

It is interesting to note that nearly all the locations listed in table 1 were formerly country estates in which many exotic plants and trees, including the Turkey oak, would have been introduced at some time in the past. A closer search of these areas could well confirm the presence of Turkey oaks somewhere in the vicinity. Although exceptionally large numbers of Knopper galls were found on some of the oaks in Mar Hall grounds during 2002, it is unlikely that their presence there would have been overlooked during visits to the area in 2001. Acorns are produced every year, but it is only every second year that large numbers mature. In alternate years large numbers of young fruits are produced but are aborted in June and July. Observations showed those oaks, which were heavily infected by Knopper galls in 2002, produced only a few galls in 2003. Others oaks which were only lightly or unaffected by the Knopper gall wasp in 2002 were found to be heavily infected with galls in the following year.

ACKNOWLEDGEMENTS

The authors are grateful to Geof Hancock for confirming our identification of the insects that emerged from the galls. Many thanks to Graham Stone for sending various papers relating to the life history of the Knopper gall wasp and thanks also to John Mitchell, Dr Keith Futter and Dr Patricia Walker for sending details of their unpublished records of recent discoveries of Knopper galls.

REFERENCES

Hancock, E.G. (2001) Alien insects in Scotland, *Glasgow Naturalist Supplement* 23,57-65

Muscot, J. (2001). Report of an outing to Gosford 16 September 2000, *Journal of the Edinburgh Nat. Hist. Society* March 2001, 44-45

Stone, G.N. et. al. (1995). *Geographic and between-generation variation in the parasitoid communities associated with an invading gallwasp, Andricus quercuscalicis* Oecologia (1995) 104: 207-217

Table 1. Knopper gall observations made during September/October 2002, 2003 and 2004

Lanarkshire (VC77)

Location	grid ref.	galls found	Turkey oak
Chatelherault C. Park	NS 539737	4	present at Low Parks
Strathclyde C. Park	NS 735583	3	present at Low Parks

Renfrewshire (VC76)

Location	grid ref.	galls found	Turkey oak
Mar Hall Hotel parkland *	NS 725455	250+	16 trees present in parkland
Gleniffer Braes C. Park	NS 608480	3	probably
Paisley, Renfrew Road	NS 489650	4	none known
Renfrew, Clyde Walkway	NS 500689	50+	2 trees at Renfrew Golf Course
Renfrew, North Deanpark	NS 514672	5	present as above

* formerly Erskine Disabled Servicemen Hospital

Dunbartonshire (VC99)

Location	grid ref.	galls found	Turkey oak
Ardmore Point	NS 785317	4	probably
Gartocharn	NS 425860	25+	2 trees present
Strathleven Park	NS 399779	2	none found
Balloch Country Park	NS 388835	1	4 trees present
Ross Priory	NS 415875	3	probably
Canniesburn Care Home	NS 545712	2	probably (near Garscube Estate)
Erskine Bridge (north)	NS 465725	100+	across river at Mar Hall
Drymen	NS 481888	1	not known
Cameron House	NS 375832	10+	probably (near Balloch Park)
Dumbarton Castle	NS403746	1	not known

Perthshire (VC 88)

Location	grid ref.	galls found	Turkey oak
Battleby	NO 085291	2	probably

Editors Note: the coloured illustrations to this article are on the front cover of this issue of the Glasgow Naturalist.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 133-135.

RECORDS OF COLEOPTERA FROM ISLAY

O. Vorst
Poortstraat 55, 3572 HD Utrecht, The Netherlands
Email: <vorst@xs4all.nl>

ABSTRACT

A collection of Coleoptera from the Inner Hebridean island of Islay has yielded 552 specimens representing 71 species. Collections were taken from beach and coastal dunes, river banks, moorland, and sheep carrion. Eighteen of the 71 species appear not to have been previously recorded from Islay. Five of the 71 species are new records for the Inner Hebrides. These five species were all collected from the sandy banks of a small river.

INTRODUCTION

The Coleoptera of the Inner Hebridean islands are imperfectly known. During a short stay on the Inner Hebridean island of Islay from 28 April to 1 May 2002 the weather conditions allowed me to undertake some sampling of this group. My efforts were limited in time and mainly confined to the close vicinity of the Machrie Hotel a few kilometres northwest of Port Ellen on the southern part of the island, and resulted in a list of only 71 species, based on 552 specimens (Table 1). To my surprise eighteen of those were not mentioned for Islay in the list of Coleoptera of the Inner Hebrides by Welch (1983), nor in the additions by Sinclair (1988, 1991) or the water beetle survey of the island by Foster & Eyre (1988), and thus should be considered additions to the list for Islay Coleoptera. Five species are recorded for the first time from the Inner Hebrides.

RESULTS

The 71 species collected, based on 552 specimens, together with their habitats are shown in table 1. The records are grouped according to four main habitat types as follows.

***Beach and coastal dunes* (B),** between Machrie River and Kintra River (NR3148, NR3150, NR3248, NR3249, NR3250). Sparsely vegetated sand dunes, partly occupied by a golf course, beaches with some drift-wood, wrack and a dead gannet (both sifted), and marine rock pools.

***River banks* (R)** of the Machrie River (NR3250). In the sampled part the rivulet flows through a moorland area within a steep, peaty embankment, before slicing through the coastal dunes to form exposed sandy banks. In both stretches the riparian fauna was sampled by flushing the banks and collecting the resulting floating debris.

***Moorland* (M),** near Kintra and Loch Eidhinn (NR3249, NR3250). Dry open heathland (sifted), flowering *Ulex europaeus* (beaten) and moorland including a peat cutting pool (netted) were sampled in this habitat.

***Sheep carrion* (S),** a dead sheep in a late state of decomposition in exposed conditions near Braigo (NR2271).

SPECIES NEW TO THE INNER HEBRIDES

The following five species are new to the Inner Hebrides.

***Georissus crenulatus* (Rossi)** – A single specimen flushed from the sandy banks of the Machrie River, only a few hundred metres from the sea (28.vi.2002, NR320504). A typical species of exposed sandy banks, both along standing and streaming waters.

***Carpelimus similis* (Smetana)** – A single male together with the previous species. Another species typical of sandy river banks. Until recently confused with its close allies, *C. rivularis* (Motschulsky) and *C. bilineatus* Stephens (Owen, 1993), neither of which has been reported from the Inner Hebrides (Welch, 1983).

***Bledius terebrans* (Schiödte)** – One specimen collected at the same site as the above-mentioned species. Another typical inhabitant of water margins, where it buries in the soil.

***Bledius subterraneus* Erichson** – Five specimens were flushed from the sandy embankment of the Machrie River a few hundred metres more inland (28.vi.2002, NR324503). Yet another riparian species.

***Tachyporus dispar* (Paykull)** – This rove beetle species has only recently been separated from *T. chrysomelinus* (L.) (Booth, 1988). The latter species is mentioned from Islay by Welch (1983), but this record may as well refer to *T. dispar*. Two specimens were collected along the Machrie River (28.vi.2002, NR320504 & NR324503).

DISCUSSION

Certainly the Coleoptera of the Inner Hebridean islands are still imperfectly known, as a small collection of beetles from Islay resulted in five additions to the list of these islands. Remarkably enough they are all from the same habitat, the sandy banks of a small river. This probably just shows the little effort that has been made to sample this particular habitat in the past.

ACKNOWLEDGMENT

I would like to thank Prof. G.N. Foster for his stimulating assistance in preparing this article.

REFERENCES

Booth, R.G. (1988). The identity of *Tachyporus chrysomelinus* (Linnaeus) and the separation of *T. dispar* (Paykull) (Coleoptera; Staphylinidae). *Entomologist* 107, 127-133.

Foster, G.N. and Eyre, M.D. (1988). The water beetles of Islay. *Glasgow Naturalist* 21, 423-431.

Owen, J. (1993). An annotated list of recent additions and deletions affecting the recorded beetle fauna of the British Isles. *Coleopterist* 2, 1-18.
Sinclair, M. (1988). Some Coleoptera new to Islay (V.C. 102) including two species unrecorded from the Inner Hebrides. *Glasgow Naturalist* 21, 493-494.
Sinclair, M. (1991). Two beetles (Coleoptera: Staphylinidae) from Islay (V.C. 102). *Glasgow Naturalist* 22, 87-88.
Welch, R.C. (1983). Coleoptera in the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B, 505-529.

Table 1. List of beetles recorded from Islay, 2002.
Species new to the Inner Hebrides are marked **, species new to Islay *.
Beach and coastal dunes (B), River banks (R), Moorland (M), Sheep carrion (S).
Notation in table. Example:
CARABIDAE *Bembidion pallidipenne*.
Beach and coastal dunes (B).
2/23 = records/specimens (23 specimens recorded from 2 sites).

	B	R	M	S
CARABIDAE				
Clivina fossor (L.)	1/1	.	.	.
Broscus cephalotes (L.)	1/1	.	.	.
Bembidion pallidipenne (Ill.)	2/23	1/5	.	.
B. tetracolum Say	.	1/2	.	.
Paranchus albipes (F.)	1/1	1/6	.	.
Amara communis (Panz.)	.	1/1	.	.
HALIPLIDAE				
Haliplus lineatocollis (Marsh.)	1/1	1/1	.	.
DYTISCIDAE				
Hydroporus gyllenhalii Schdte.	.	.	1/2	.
H. melanarius Sturm	.	.	1/2	.
H. pubescens (Gyll.)	.	.	1/6	.
Agabus bipustulatus (L.)	.	.	1/1	.
Ilybius montanus (Steph.)	.	.	1/4	.
HYDRAENIDAE				
Hydraena cf britteni Joy	.	1/1	.	.
Ochthebius lejolisii Muls. & Rey	1/2	.	.	.
Limnebius truncatellus (Thunb.)	.	2/2	.	.
GEORISSIDAE				
** *Georissus crenulatus* (Rossi)	.	**1/1**	.	.
HYDROPHILIDAE				
Helophorus brevipalpis Bedel	1/22	1/4	.	.
H. flavipes F.	.	2/2	1/1	.
Cercyon littoralis (Gyll.)	3/23	.	.	.
Megasternum concinnum (Marsh.)	.	1/1	.	.
Anacaena globulus (Payk.)	1/1	2/27	1/7	.
HISTERIDAE				
* *Margarinotus striola* Sahlb.	.	.	.	1/1
SILPHIDAE				
Oiceoptoma thoracica (L.)	.	.	.	1/1
PTILIIDAE				
* *Ptenidium punctatum* (Gyll.)	1/78	.	.	.
STAPHYLINIDAE				
Omalium laeviusculum Gyll.	2/34	.	.	.
O. riparium Thoms.	3/38	.	.	.
* *Lesteva pubescens* Mannh.	.	1/2	.	.
** *Carpelimus similis* (Smet.)	.	**1/1**	.	.
Anotylus maritimus Thoms.	1/1	.	.	.
Bledius fergussoni Joy	1/2	1/2	.	.
B. longulus Er.	1/4	1/9	.	.
** *B. subterraneus* Er.	.	**1/5**	.	.
** *B. terebrans* (Schdte.)	.	**1/1**	.	.
* *Stenus brunnipes* Steph.	.	.	1/1	.
S. impressus Germ.	.	.	1/3	.
* *S. juno* (Payk.)	.	2/2	1/1	.
S. nitidiusculus Steph.	.	2/7	1/1	.
* *Gyrohypnus angustatus* Steph.	.	.	1/1	.
Xantholinus glabratus (Grav.)	1/1	.	.	.
Cafius xantholoma (Grav.)	1/1	.	.	.

Philonthus cf sordidus (Grav.)	1/1	.	.	.
Gabrius osseticus (Kol.)	1/1	1/1	.	.
Creophilus maxillosus (L.)	1/1	.	.	.
Quedius tristis (Grav.)	.	.	.	1/1
** *Tachyporus dispar* (Payk.)	.	**2/2**	.	.
* *Myllaena brevicornis* (Matth.)	.	2/2	.	.
Aloconota gregaria (Er.)	1/1	.	.	.
Amischa bifoveolata (Mannh.)	.	1/2	.	.
Atheta amicula (Steph.)	1/1	.	.	.
A. fungi (Grav.) s.l.	.	1/1	.	.
* *A. obtusangula* Joy	.	1/2	.	.
A. vestita (Grav.)	3/117	.	.	.
Acrotona aterrima (Grav.)	1/1	.	.	.
* *Aleochara grisea* Kr.	2/2	.	.	.
* *A. obscurella* Grav.	2/4	.	.	.
A. punctatella Motsch.	3/18	.	.	.
PSELAPHIDAE				
Bryaxis bulbifer (Reichb.)	.	1/2	.	.
SCIRTIDAE				
Cyphon hilaris Nyh.	.	.	1/1	.
* *C. ochraceus* Steph.	.	.	1/1	.
C. palustris Thoms.	.	1/10	1/3	.
DRYOPIDAE				
Dryops ernesti Goz.	.	1/1	.	.
D. luridus (Er.)	1/1	1/2	.	.
NITIDULIDAE				
Epuraea aestiva (L.)	.	.	1/1	.
CRYPTOPHAGIDAE				
Micrambe vini (Panz.)	.	.	1/16	.
Atomaria sp.	1/1	.	.	.
SCARABAEIDAE				
Aegialia arenaria (F.)	1/1	.	.	.
Serica brunna (L.)	1/1	.	.	.
CHRYSOMELIDAE				
* *Asiorestia ferruginea* (Scop.)	.	1/2	.	.
APIONIDAE				
Apion haematodes Kirby	.	1/1	.	.
CURCULIONIDAE				
Philopedon plagiatum (Schall.)	.	1/1	.	.
* *Rhinoncus pericarpius* (L.)	.	.	1/1	.

Summary of data	B	R	M	S	
Total [records/specimens]	5/385	3/111	3/53	1/3	Σ 12/552
Number of species	31	33	18	3	Σ 71

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 137-140.

ABUNDANCE AND PATTERNS OF OCCURENCE IN BUTTERFLIES FROM AILSA CRAIG, AYRSHIRE

B Zonfrillo[1] & E G Hancock[2]
[1]Ornithology Unit, DEEB,
[2]Hunterian Museum (Zoology)
Graham Kerr Building, University of Glasgow, Glasgow G 12 8QQ

ABSTRACT

21 species of butterflies have been reported from Ailsa Craig. 5 breed regularly and 12 are sporadic in their appearance on the island. Two or three species records are considered dubious. All records following are fully documented.

INTRODUCTION

The flora of Ailsa Craig is now relatively well known (Zonfrillo, 1994) but its butterflies have received little attention for over half a century. There are apparently no systematic collections from the past and only scattered observations have been committed to print (Scott, 1899; Smith et al., 1900; Gibson, 1952, 1976.) with some of these records requiring corroboration. Vegetation cover on the island had probably not altered drastically during the first half of the 20th century. It was largely grazed in all the places accessible to grazing mammals. Until the late 1950's feral goats, sheep, Soay sheep, ponies and donkeys were the main herbivores on Ailsa Craig with all but the former belonging to those who made their living on the island as hewers of granite and part-time crofters. Add to that innumerable alien rabbits and rats and what was left of the natural non-grazed vegetation, suitable for many butterflies, was largely confined to inaccessible cliff ledges. Plant life over much of the island was in consequence much degraded and constantly suppressed through the action of these grazing herbivores. Human and mammalian activities on Ailsa therefore indirectly affected the abundance and species of the butterflies breeding on the island. During the early 1960's all domestic mammals plus feral goats were removed and in 1991 Brown Rats were totally eradicated by poisoning (Zonfrillo, 2002). This activity also reduced greatly the numbers of Rabbits on the island, but was temporary and the Rabbits soon regained their former population levels. In 2003 Rabbit numbers were again reduced – this time by disease, but it remains to be seen if any will survive and flourish (Zonfrillo *et al*, 2003). Partly caused by herbivore grazing it is evident therefore that even short-term changes in the flora have probably contributed to the presence and abundance of certain butterflies on Ailsa Craig. Gardening by lighthouse keepers, before automation, may also have added variety to the local flora and been a source of food for some butterflies.

Migrant and resident species, normally confined to the mainland or other Clyde islands, usually reach Ailsa following periods of prolonged strong winds. Though this could happen perhaps on an annual basis, certain wind-drifted migrants seem to have difficulty becoming established on the island, even when their food-plants are present and abundant. The persistent strong winds that blow over Ailsa may inhibit some species establishing themselves on an otherwise exposed island and salt spray may render many plants inedible to their caterpillars. The presence of breeding Rock and Meadow Pipits on Ailsa, inveterate caterpillar eaters, may also play a part in the absence or presence of certain butterflies.

There appears to have been no systematic collection of butterflies from Ailsa Craig during the 20th century. From the 1960's onwards, visiting entomologists have helped build up a picture of butterfly species present on the island but perhaps more importantly, their records have been published or voucher specimens preserved for posterity. In recent years all the Lepidoptera – butterflies and moths - of Ailsa Craig has been recorded in greater detail than ever before, building an impressive list of species present, of which the butterflies here recorded form a small part.

Those who have contributed observations to this paper along with the authors are as follows. Thomas Daniels,(TPD), Dr Mike V Hounsome (MVH) the late Ian Christie, (IC), Keith Bland (KPB) Shona Quinn, (SQ), Steven Zonfrillo (SZ), Robyn Anne Stewart (RAS), Dr Sarah Wanless (SW), Alistair Young (AY) and the late F Gerald Rodway (FGR). We are grateful for their records and fieldwork.

RESULTS

List of Butterfly species recorded from Ailsa Craig.

*An asterisk denotes a breeding record. The names follow the Bradley (2000) checklist.

***Erynnis tages* (Linn.) Dingy Skipper**

While on a Glasgow Naturalist's day visit to the island the late F G Rodway disturbed a Dingy Skipper on the south path on 6 June 1976. This was the first record for Ailsa of a species that is generally rare in Scotland but occurs locally on the south Ayrshire coast. There are no further records to date.

Observer; FGR

***Colias croceus* (Geoffroy) Clouded Yellow**

On 17 May 1992 BZ recorded the first two individuals of this species during an influx of migrant Lepidoptera including several Painted Ladies and 4 Hummingbird Hawk Moths. The

Clouded Yellows were seen almost daily thereafter until 19 August 1992 with several records of up to 3 individuals at one time. On 30 September 2000, during another smaller influx, a male and a female were recorded. Sutcliffe (1994) summarised all the Scottish records of this species recorded during the major influx in 1992.
Observers ; BZ, MVH & TPD.

***Pieris brassicae* (Linn.)** ***Large White**
This is listed by Smith *et al.* (1900). The Large White fluctuates in numbers annually on Ailsa Craig. Their numbers may depend on climatic factors and the abundance of the Sea Radish *Raphanus raphanistrum* ssp. *maritimus* plants growing mainly on the south side of the island. In some years, for example in May 1990, up to 200 individuals were counted. In other years they can be scarce with only a peak of 10 individuals recorded, as in May 1991. Recent counts include 47 on 8 Aug 2001. In all of August 2002 a maximum of 3 was counted. The earliest date for this species seen on the wing is 7 May 2000. It breeds on the island feeding mainly on the Sea Radish.
Observers; BZ, TPD, SQ & SZ.

***Pieris rapae* (Linn.)** ***Small White**
By no means ever as abundant as the Large White, Small Whites are seen in small numbers in most years. The largest count was of 17 in May 1993. This species may also feed on Sea Radish, the only common Brassicacea on the island, that fluctuates in numbers from year to year, and therefore will sometimes be in direct competition with Large White.
Observers ; BZ /TPD

***Pieris napi* (Linn.)** ***Green-veined White**
This species appears regularly each year in small numbers of up to 20 individuals. Most records are in July & August, when they are on the wing. It is not uncommon and seems to suffer less from windy weather than the other two whites being better adapted to the frequently strong winds.
Observers ; BZ, TPD, SQ & RAS.

***Callophrys rubi* (Linn.)** **Green Hairstreak**
One specimen was caught on 1 May 1990, at the south cottage following strong southerly winds and warm temperatures. Specimen in Glasgow Museum [Reg. No DB.7547]. It occurs on the mainland coasts within sight of the island. This appears to be the first Ailsa record.
Observers ; BZ

***Lycaena phlaeas* (Linn.)** **Small Copper**
In recent years only one specimen has been seen, on 19 Jul 1984. Always scarce, this species appeared mainly in the old garden areas associated with the lighthouse, where Common Dock grew. Now overtaken by Bracken the dock is scarce in these areas and this species has failed to appear in most of the past decades. K Bland recorded it on a day visit in the 1980's and Gibson (1952) states that it "occurs from time to time".
Observers ; BZ & KPB

[*Aricia agestis* (Denis & Shiffermüller)
Brown Argus]
This is a dubious record for Ailsa Craig hence placed in square brackets. Gibson (1952) recorded this species, " a few each year around the Castle Flat, c.400ft". Thomson (1980) suggested all reports of this species in Scotland, including this record, refer to the Northern Brown Argus. There are no other records from visiting entomologists before or since then, in what would have been a notable location. The species – regarded as distinct from 1958 onwards - does not occur in Scotland and the nearest breeding records are on the west side of Britain in north Wales. The food plant of the more likely Northern Brown Argus, *Aricia artaxerxes,* a different but easily distinguished species, is the Rockrose *Helianthemum*, found on the Ayrshire coast opposite Ailsa Craig. However this plant has never been recorded from the island hence even migrants are unlikely to reproduce.

***Polyommatus icarus* (Rottemberg)**
***Common blue**
There are enough records of this species on the island over the years to suggest that with the right food plants in abundance it will breed. Gibson (1952) stated that it was fairly common but just over 20 years later this was not the case. Wanless (in litt) recorded it on 21 Jun 1974 and again on 8 Jul 1976 until the end of that month.
The abundance of this species appears related to the abundance of Bird's foot Trefoil *Lotus corniculatus* and White Clover *Trifolium repens*. When rabbit numbers were reduced in 1991 these plants became abundant and shortly thereafter, from 7 - 29 Jul 1994 the Common Blue was present every day on the island, 1 male on 7 Jul 1994 and up to 3 males by 3 Jul 1995 A voucher specimen is lodged with Glasgow Museum [Reg. No DB.7548]. These clearly became established and up to 15 individuals, of both sexes, were recorded on 25 Jul 1997. By 1998 rabbits were again expanding their numbers and grazing out the *Lotus* and *Trifolium* with only 3 Common Blues recorded in 1999 and 1 on 22 Jun 2000. None was recorded in 2001 or in 2002. With the decline in rabbits during 2003, the species re-appeared with the increase in *Lotus* and will hopefully re-establish itself as part of the island's fauna.
Observers ; BZ, SW, SQ & TPD,

***Vanessa atalanta* (Linn.)** *** Red Admiral**
This is a very regular summer and autumn migrant to Ailsa with breeding recorded in 1989: from 2 pupae, imagos emerged on 8 Aug 1989 (Zonfrillo, 1990) and a specimen is in Glasgow Museum [Reg. No DB.7549]. A probable over-wintering individual was seen on 21 Apr 1987 and another spring record was seen at Garry Loch on 30 May

1994. The species is usually seen in summer and autumn in small numbers of less than 10 records per annum, but in 2002 some 30 to 40 individuals were observed during August.
Observers ; BZ, TPD, MVH & RAS

***Vanessa cardui* (Linn.) * Painted Lady**
This butterfly is a migrant visitor to Ailsa Craig, and is somewhat sporadic. It appears most years as a spring or late summer migrant but may sometimes be unrecorded. Gibson (1952) recorded one in July 1947. Three were recorded on 22 May 1992 and again in 1994. In June 1996 some females had laid eggs on Creeping Thistle plants at the Gashouse wall. Caterpillars were subsequently seen in August 1996. In August 2002 some 12 individuals were present during an influx. In 2003 it was common in autumn with up to 10 seen in one day.
Observers ; BZ, TPD, RAS

***Aglais urticae* (Linn.) *Small Tortoiseshell**
Listed firstly by Smith *et al.* (1900), this is a common and regular breeding species on the island. Hibernating individuals are common in the old buildings on Ailsa and larvae feed on the abundant Stinging Nettles. It is probably the only butterfly to have been recorded alive in every month of the year on Ailsa Craig. Active flying has been noted from February onwards until November. It over-winters in buildings and cliff crevices and on warm days these specimens can be active. Up to 60 individuals have been counted in summer in one day.
Observers ; BZ, TPD, SQ, RAS

***Inachis io* (Linn.) *Peacock**
The Peacock butterfly is a somewhat irregular visitor to Ailsa with most records occurring in spring and summer. Gibson (1952) first recorded the species in August 1948 and in September 1949. Wanless (*in litt.*) recorded it on 27 Mar 1974. Larvae were recorded on 16 June 1984. Recent spring records were from 9 May onwards until late October 2000. It was common in 2001, with up to 8 individuals seen. 20 Peacocks were counted in May and 12 in August 2002. In July 2003 it was again numerous.
Observers ; BZ, TPD, SZ.

***Boloria selene* (Denis & Shiffermüller)**
Small Pearl-bordered Fritillary
One example was recorded on 29 Jun 1984. Both Dog Violet *Viola riviniana* and Marsh Violet *Viola palustris*, the food-plants, occur on Ailsa, the former in abundance, but the species appears to have remained absent apart from this single record – presumably a wind-drifted migrant.
Observer ; A Y.

***Argynnis aglaja* (Linn.) Dark Green Fritillary**
Gibson (1952) recorded this species (August 1948, one specimen), presumably a wind-drifted migrant. There are no further records.

***Erebia aethiops* (Esper) Scotch Argus**
There is one record only for Ailsa Craig. During a day of strong northerly winds a single Scotch Argus was seen on thistles at the Gashouse on 8 Aug 2001. It flew off strongly when disturbed and was not seen again. In all probability it may have been wind-drifted from Arran. Asher *et al,* (2001) mention mark-recapture studies of this species where maximum movements recorded were 100 metres in England and 500 metres in Switzerland. At 15 kilometres from the nearest land, Ailsa Craig shows these recorded movements and measurements to be somewhat conservative.
Observers; BZ, SZ

***Hipparchia semele* (Linn.) Grayling**
Gibson (1952) recorded this species, - "three records; all west cliffs." and later (Gibson, 1977), claimed a gradual increase since 1972 and added a record of 12 at one time in 1976. However, in June 1976 four experienced lepidopterists also visited Ailsa Craig and failed to record the species anywhere on the island. If the twelve together were an influx or an emergence then predators had probably rapidly eliminated them. It occurs on the mainland opposite Ailsa and is not uncommon, but it has clearly not established itself on the island.

***Maniola jurtina* (Linn.) Meadow Brown**
Although common on the mainland, this butterfly is a very scarce visitor to Ailsa. A "brown" butterfly seen on 23 Jul 1989 may have been this species. No further records were noted until on 20 Jul 1992 when a female was caught and released following strong SW winds.
Gibson (1952) recorded this species as "common" in 1952 although there were no other records before then and none until 37 years later. It is clearly not common on Ailsa Craig and its occurrence is perhaps related to wind-drift. It has clearly never established itself despite its food plants - various grasses - being abundant.
Observers ; BZ, SQ.

[*Coenonympha pamphilus* (Linn.) Small Heath]
Gibson (1952) alone recorded this species on Ailsa, stating that it was "fairly common on summit grass". There are no other records. It is certainly common enough on the mainland in the right habitat but strangely absent from Ailsa Craig. If colonisation had occurred it was very temporary.

[*Coenonympha tullia* (Müller) Large Heath]
This is a puzzling occurrence: Gibson (1952) recorded this scarce species as follows - "Five specimens recorded; all in region of Garry Loch, (c. 800ft)". There are no other sightings of this species before or since. On mainland sites it is reported as feeding on various Cotton-grasses *Eriophorum* and Purple Moor Grass *Molinia caerulea*. Neither plant species is present on Ailsa, nor ever has been, nor is the butterfly generally common in Strathclyde. There are no specimen or photographic records of

this or the previous species from the island and both should be regarded as of dubious occurrence, hence are placed in square brackets.

Aphantopus hyperantus **(Linn.)** **The Ringlet**
Two individuals were seen and photographed on 3 Sep 1996, near the south cottage on Ailsa. This was the first time the species had been recorded on the island. A specimen is preserved in Glasgow Museum [Reg. No DB.4071]. In early July 2003 another individual was recorded, again probably wind-drifted. This species has been seen on the Ayrshire coast opposite Ailsa and is also found on Arran.
Observers ; BZ, TPD & RAS

ACKNOWLEDGEMENT

We are grateful to the Blodwyn Lloyd Binns fund of the GNHS for a grant towards this study.

REFERENCES

Asher,J., Warren, M., Fox, R., Harding, P., Jeffcoate, G., and Jeffcoate, S. 2001. *The Millennium Atlas of Butterflies in Britain and Ireland.* Oxford University Press.

Bradley, J.D. *Checklist of Lepidoptera recorded from the British Isles* 2nd Edition (Revised). Bradley & Bradley.

Gibson J A (1952). The Butterflies of Ailsa Craig. *Scottish Naturalist* 64: 112-113.

Gibson J A (1977) Grayling Butterflies on Ailsa Craig *The Western Naturalist* 5: 114.

Smith, J., Patterson, J., & Watt, H. B. (1900). The Natural History of Ailsa Craig. *Ann. Andersonian Nat. Soc.*, 2: 135-154.

Sutcliffe R (1994). The Clouded Yellow invasion of Scotland, 1992. *Glasgow Naturalist*. 22; 389 – 396.

Thomson,G. 1980 *The Butterflies of Scotland: A Natural History*. Croom Helm.

Zonfrillo, B. (1994). The Flora of Ailsa Craig. *Glasgow Naturalist.* 22 : 4. 307 – 344.

Zonfrillo, B. (2002). *Wildlife Conservation on Ailsa Craig*. Thomas Duncan Memorial Lectures, Friends of the McKechnie Institute, Girvan, Scotland.

Zonfrillo B, Thomson H & Stewart R A, 2002 Rabbit Calicivirus Disease on Ailsa Craig, Ayrshire in 2003 *The Glasgow Naturalist 24:1 : 102 - 103*

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 141-143.

SHORT NOTES

UNUSUAL COLOUR FORMS OF THE WOODLOUSE *PORCELLIO SCABER (Latreille)* ON MULL

Glyn M. Collis & Dawn Collis
Flat 2, Hawthorn Park, Argyle Place, Rothesay, Isle of Bute, PA20 0BA.
<g.m.collis@warwick.ac.uk>
<dawncollis@hotmail.com>

During a visit to Mull (VC103) in August 2002 we found two unusual colour forms of the common rough woodlouse *Porcellio scaber* (Latreille), neither of which we had seen before during 35 years of looking at woodlice. On the north side of Loch Spelve (grid ref NM675269) we found a specimen with a colour that might best be described as aquamarine or royal blue, with just a hint of slatiness. The colour did not fade in alcohol. Presumably this individual was infected with *Iridovirus*, but it did not have the purplish hue not uncommonly seen in *Trichoniscus pusillus* when infected with *Iridovirus* (colour plate in Hopkin, 1991). On the south shore of Loch Spelve (grid ref NM679261) we found an albino *P.scaber*, completely lacking pigment even in the eyes. Just the gut contents showed as a dark stripe. At both these sites, other well-grown individuals were all the usual slatey grey colour.

We are aware of other reports of albino and other abnormal colour forms of this and other species (e.g. Hopkin, 1989; Wijnhoven & Berg, 1999), but we were most surprised that these two very unusual finds were in close proximity to one another, especially as we are not aware of any indication that the two rather different conditions could be caused by the same factors.

References

Hopkin, S.P. (1989). 'Albino' Woodlice: do they exist? *Isopoda* 3, 29-31.

Hopkin, S. (1991). A key to the woodlice of Britain and Ireland. *Field Studies*, 7, 599-650. (Re-printed as an AIDGAP publication, offprint No. 201, Field Studies Council, Shrewsbury.)

Wijnhoven , H. & Berg, M.P. (1999). Some notes on the distribution and ecology of *Iridovirus* (Iridovirus, Iridoviridae) in terrestrial Isopods (Isopoda, Oniscidae). *Crustaceana, 72, 145-156.*

AN ANCIENT BEETLE COLLECTION SAVED

Ronald M. Dobson
7 Netherburn Avenue, Glasgow G443UF

During the late 1980s, while rummaging amongst the miscellaneous unused or discarded old equipment dumped in the basement beneath the Zoology Section of the Hunterian Museum at Glasgow University, I decided to take a close look at an old cabinet of pinned beetles which, lying open and partially on its back, was in a sorry state. The cabinet was very dilapidated. Several drawers were missing (but were later found remote from the cabinet), some had the glass cracked and one lacked it completely. Five of the spacers between drawers were lost and 19 of the 32 ivory drawer knobs were broken. Judging by the thick coating of sooty grime on the unglazed drawer, the collection must have been there for many years. As it seemed certain that it would be consigned to a skip at a future clear out, I bought it, primarily with a view to adapting the remains of the cabinet to house my own meagre collection. It soon became evident, however, that it might be worth trying to save the collection itself so I proceeded to repair the cabinet, to a functional standard, making new spacers, casting replica knobs from epoxy resin and replacing glass where necessary. Drawers were repapered and provided with pockets for mothballs.

The collection was clearly very old with many specimens dating from around 1860 and one being labelled 1840. As might be expected the names and arrangement of species differed greatly from present day usage so a complete rehabilitation was necessary. This took several years as a part-time activity and modern checklists could not cope with many of the out-dated names. However, in about 1945, I bought a set of Fowler's classic handbooks on beetles (6 volumes including supplement published between 1889 and 1913) in the second-hand department of a Glasgow bookshop and, although I knew that this work was outdated I thought it would help me to determine the few beetles in my personal collection. These books proved indispensable to the present project because not only did they give descriptions and names current at the time of publication but they also listed numerous synonyms so that most specimens in the collection could be attributed to the names listed by Pope, 1977.

The outcome of this is that I now have an (almost) up-to-date collection of rather more than 17,500 British specimens, arranged according to Pope's list, in a 32-drawer, sound but somewhat battered, cabinet. This has proved most useful in my on-going efforts to determine material from the extensive collections, taken around 1900 by enthusiasts such as J.F.F.X. King, which are stored in the Hunterian (Zoology) Museum.

It is unfortunate that Staphylinidae, except for a few species added by myself, are entirely lacking and many Nitidulidae in the drawer lacking glass had been lost. Even allowing for these deficiencies over 87% of the (non-Staphylinid) genera listed by Pope are represented.

Fowler's books not only describe species and provide keys for their determination but also give notes on localities of occurrence along with the names of collectors. Relatively few specimens bore adequate data labels, but amongst those that did examples caught and labelled by some twenty 19th Century enthusiasts were found. This, of course,

helped to ensure the authenticity of identifications. Occasional individuals bore data which accorded with details given by Fowler, for example, a specimen of the rare Colydiid Endophloeus markovichianus (Piller & Mitt.), first recorded from Britain by Turner in the New Forest in 1862, and regarded as one of his "great finds", bears his label from the same locality. Amongst others, the name "Dr Power" occurs throughout and the private collection of water beetles of the well-known "Sam Stevens" is embodied.

In general specimens are in good condition but some, especially from damaged drawers, are filthy and others had to be re-pinned. Such defective specimens are being reconditioned as they are required.

Certain species are of particular interest. One minute non-British Scolytid bears the name Hypothenemus eruditis Westwood because it was first found in the cover of an old book, and at the other extreme were two examples of the large Scarabaeid, Polyphylla fullo (Fabricius), a name some might think (incorrectly) descriptive of the repaired cabinet! This species, an uncommon denizen of Central and Southern Europe, has occasionally been found in Kent and one of the present specimens was found dead on the sand hills of Deal, a location mentioned by Fowler, 1890.

The origin of the collection is obscure but, along with Mr. E.G. Hancock of the Hunterian Museum, attempts are being made to elucidate this. It is hoped that a collaborative evaluation of the collection can be made in the near future and that eventually it will be returned to the Museum.

I am grateful to Mr. Hancock for his advice and help, to Mrs. Moira Murray for showing me how to make replacement drawer knobs and to Mr. John Dobson for replacing damaged glass.

References

Fowler, W.W. (1887- 1913) The Coleoptera of the British Isles, 1-5 and 6 (supplement). London .

Pope, R.D. (1977) Kloet and Hincks, A Check List of British Insects Ed. 2, Pt 3, Coleoptera and Strepsiptera. London.

LARGE-LEAVED AVENS *(GEUM MACROPHYLLUM)* ESTABLISHED AT MUGDOCK COUNTRY PARK (VC86).

Bill Hansen

10 Craigton Avenue, Milngavie, Glasgow G62 7SX

In 1999 Prof. J. H. Dickson visited Alaska and brought home, as usual, seeds and amongst them were *Geum macrophyllum*. The seeds germinated and as a result some healthy plants were raised. In 2001 Prof. J.H. Dickson was on a walk through Mugdock Country Park and spotted what he thought was a *G. macrophyllum* and asked me to visit the site and possibly verify the discovery. I duly obliged and came to the same conclusion that it was indeed *G. macrophyllum*.

Interestingly it seems to vary from the Alaskan plant, which is growing in my garden, in that the terminal lobe of the basal leaf is orbicular in shape where as the former is distinctly three-lobed. Recently, July 2003, I had the opportunity to visit the Herbarium at ERBG to have a look at the specimens collected on the west coast of America and Canada from Alaska down to Nevada and New Mexico. It became clear that it is a variable species. The specimens were collected from sea level to 7000 feet and in various habitats.

This species is not native to Britain and the plant(s) have possibly been 'imported' during the time the Craigton Castle and the stables, which are now the Visitor Centre, were occupied.

Clements and Foster (1994) p. 138 state:

"An established garden escape; naturalised on roadsides and river banks, mainly in Scotland". Interestingly, apart from Mugdock Country Park, only other recorded wild populations are in East Scotland in Angus, Moray and East Ross-shire. In the West of Scotland it can be found in 'Linn Botanical Garden', Cove, Argyll.

How did it come to the Park?

The most likely explanation is that once upon a time it was introduced as a garden plant at the now ruined Craigend Castle, although to date it has not yet been found near this ruin. Another possibility, though rather remote, it is as an 'Animal Feed Alien' since the site is near the former stables.

Nevertheless, the plant has established itself and is regenerating, as plants of various ages can be found for approx. 100 metres on both sides of path, though mainly on the right side, leading from the Visitor Centre towards the ruined castle. In late July 2003 some 50+ plants were counted though some may have been missed. It is possible that more plants could be found were it not for the proliferation of the Stinging Nettle (*Urtica dioica*) plus the effect of people, dogs and children frequenting the Park and, as I have seen, plants being swiped with sticks by children consequently allowing less seeds to ripen and disperse. A survivor indeed.

There are numerous other introduced plants both terrestrial and aquatic in the park.

Reference

E.J.Clements and M.C. Foster (1994). *Alien Plants of the British Isles.* Botanical Society of the British Isles, London 1994.

THE RED-NECKED FOOTMAN IN WEST-CENTRAL SCOTLAND

John T. Knowler and John Mitchell

3 Balfleurs St., Milngavie, Glasgow, G62 8HW

22 Muirpark Way, Drymen, G63 0DX

The red-necked footman (*Atolmis rubricollis Linn.*) is a local moth with a mainly southern distribution. Skinner (1984), in *Moths of the British Isles*, gives it as widely distributed in southern counties of England and occasionally reported as far north as Lincolnshire and Staffordshire. In fact, the species was recorded near Dumfries in the1860s and was

re-discovered in Dalbeatie Forest, Kirkcudbrightshire in 1992. Since then, it has proved to be widespread and sometimes common in commercial forestry plantations in Dumfriesshire, Kirkcudbrightshire and Wigtownshire (Mearns, 1999). There are also records from Port Appin in 1986 and the Oban area in 1971 (Penny, 1987).
On the 5th October 2002, approximately 50 caterpillars of what were provisionally identified as red-necked footman were found feeding on lichen on fence posts at the eastern side of the Muirhouse Muir portion of Loch Ardinning, Scottish Wildlife Trust reserve approximately 10 miles (16 Km) north of Glasgow. On follow-up visits on 15th and 28th June, 2003, adult moths were found; sometimes resting on low vegetation but more commonly flying around the tops of the scattered and stunted (3-7m tall) downy birch (*Betula pubescens*) that are characteristic of this part of the reserve. Forty were counted in less than 30 mins. Furthermore, more moths were seen flying over the isolated birches and over a single rowan (*Sorbus aucuparia*) on more open areas of Muirhouse Muir and also over an adjacent young (7-10m high) Sitka spruce (*Picea sitchensis*) plantation .
Also on 15th June, 2003, six adult Red-necked Footmen were found near High Mains, in commercial forestry of the Buchanan Castle Estate near Drymen. A further visit on 29th June, revealed abundant moths flying around the tops of 12 – 15 m high Sitka spruce and Norway spruce (*Picea abies*) in multiple areas of the plantation.
Skinner (1984) describes the moth as inhabiting deciduous and coniferous woodland and states that the larvae feed on algae and lichen on the branches and trunks of oak, beech and several species of conifer. A possible explanation for the apparent spread of the species in the West of Scotland could therefore be that, like the crossbill, goshawk and gold crest, it has been able to take advantage of commercial conifer plantations. This cannot however be the whole story as the colony at Loch Ardinning reserve suggests an expansion into new habitats. Here, the moth flies over birch growing in rank heather. At the main site the trees are sufficiently close to each other to be collectively regarded as a small but very open copse but the moths were also associated with isolated trees. In addition, at least a proportion of the larvae at Loch Ardinning were feeding on lichen on fence posts.
The abundance of the red-necked footman at the two Stirlingshire sites described above suggests that the species will be found to have colonised other areas in Central Scotland.

References

Mearns, R. (1999) Update on three species of moth in south-west Scotland, *Entomologists Record* 111, 218-219.
Penny,C.C. (1987) *Atolmis rubricollis* in Argyllshire, *Entomologists Record* 99, 181-181.
Skinner, B. (1984) *Moths of the British Isles*, Viking.

HAWFINCHES AT TALLA RESERVOIR, PEEBLESHIRE (VC?).

Margaret M H Lyth

On 11 May 2002 at about 6.30 pm I observed three male and two female Hawfinches in a field beside Talla Reservoir near Tweedsmuir, Borders.
The birds were chasing each other and I was able to observe them with binoculars from a distance of about 25 metres. After about 5 minutes they flew off towards a nearby conifer plantation. On consulting the "*New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*" by DW Gibbons *et al.,* 1993, I noticed a lack of records from around this immediate area. Since Hawfinches are rather scarce breeding birds this observation seems noteworthy.
Hawfinches are often associated with mature woods such as large broadleaved woodland estates or parks but can also be found in coniferous woods. With their enlarged bill they are capable of cracking the stones of cherry, white beam or other such hard seeds and they are also said to be fond of peas. Being an often elusive or shy species they may be more widespread than current knowledge suggests. Their main Scottish locations are in the Borders, Lothian and Perthshire with a few outposts elsewhere.

BATS IN CLARENCE DRIVE, CLEVEDEN, GLASGOW WEST END.

David McNaught
22, Clarence Drive, Hyndland. G12 9QX.

Late in summer 2004, whilst I was admiring the dusk unfold on a balmy evening, two black arrows whizzed by. At first I thought they were starlings. Wrong. One the next night, at the same time, with the aid of a comfy chair I awaited their return. There they go – two bats, one slightly below the other. A pilot and wingman? a happy couple? Competitive siblings? I estimated their wingspan to be about six to seven inches, in other words about 15 to 18 centimetres, as deduced by measuring the gap between branches in a dead tree that they flew through. Were they Pipistrelle bats or the Common bat?
The two bats then flew across the floodlit football pitches behind Peckhams. Insects must have been milling around the vapour lamps – a candle light dinner for two? Whatever, it was a delight to watch them, dodging and playing. Who says bats don't have fun?
I believe that they live either in a local church or perhaps in the brick structures of the redundant chimneystacks of local tenements. I do hope they have planning permission, after all this is a conservation area.
Editors comment. This interesting and amusing account of the occurrence of bats in the West End conservation area of Glasgow is of some significance, as there appears to be no proper scientific data on bats in the Glasgow area.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 145-157.

BOOK REVIEWS
Compiled by Ruth H. Dobson

BRITISH BATS
John D. Altringham
New Naturalist. Harper Collins, London 2003. 218 pp. ISBN 000 220140 2 (Hardback) £35.00
ISBN 000 220147 X (Paperback) £20.00

There are fewer than fifty native land mammals in Britain and one in three of these is a bat. British Bats by John D. Altringham is a valuable contribution to our understanding of this relatively unknown group of mammals. This book is a synthesis of his earlier and comprehensive text *Bats: biology and behaviour* (Oxford University Press, 1996), but gives a much greater emphasis on species found in Britain and is written for a wider audience.

The author sets out to "describe the fascinating natural history of bats, but to do so in a functional and evolutionary context". It is a different approach to previous books in the Collins New Naturalist Series, reflecting the closer involvement of scientific research in natural history today. The first three chapters of the book provide an excellent overview of bat folklore, evolution and the biology of temperate species. Flight, echolocation, torpor, hibernation and reproduction are well described and this provides important background to Chapter 4, which is a synthesis of how form and function have shaped the ecology of British Bats. The final three chapters are likely to be of most interest to the naturalist. These contain detailed descriptions and distributions of all resident species and the most common vagrants in Britain (Chapter 5); an account of the threats to bat populations, conservation priorities and practical conservation measures, including design of bat boxes and hibernacula (Chapter 6); and my favourite chapter *Watching and Studying British Bats* (Chapter 7). This last chapter is essential reading for anyone interested in studying these fascinating animals for themselves. There is good practical advice on choice of bat detectors, image intensifiers and video cameras and how to use this equipment in the field to learn more about bat behaviour and distribution. If you are interested in undertaking more detailed studies, the author also outlines fieldwork techniques such as handling and radio-tracking bats that require a licence. The appendix gives a clear and simple identification key to British bats in the hand and a short glossary is helpful for the more theoretical chapters. There is a comprehensive bibliography and a useful list of web addresses for suppliers of equipment and bat conservation organisations. The book is illustrated with clear diagrams and tables, attractive pencil drawings and outstanding colour photographs of all resident and several vagrant species in Britain.

This book is a highly readable account of the biology of British Bats for the naturalist or bat conservationist and the author does demonstrate well the value of fitting natural history observations into a "scientifically robust evolutionary framework". **Dominic McCafferty**

GUIDE TO THE IDENTIFICATION OF SOIL PROTOZOA - TESTATE AMOEBAE
K.J. Clarke
Freshwater Biological Association Special Publication No.12.. Ambleside, 2003, pp40 ISBN 0-0900386-69-X [Price unknown]

Soil biodiversity is an understudied subject. The ground beneath our feet is teeming with small amoebae, up to a million per gram of soil. Like other soil protozoa they play an important part in controlling bacterial numbers and hence in soil fertility. Most of these amoebae are "naked" and live in the water film that surrounds soil particles. But many are "testate" - that is the body is contained in an impervious shell which projects into the air space between particles while the pseudopodia operate in movement and food capture in the water film. The shells are miracles of construction by the single-celled architect, for they are composed of plates or granules synthesised and assembled with precision by the amoeba or are put together from extraneous objects such as sand grains and diatom frustules.

After an introduction to the biology and ecology of soil testate amoebae, Ken Clarke gives a comprehensive species list and an easy-to-use identification guide to all 92 species based on shell shape, size and colour. Each succinct description is accompanied by a the author's clear black and white drawing of the shell in question. This study was based on testates found in the Natural Environment Research Council's recent Soil Biodiversity Programme, based on Sourhope in the Scottish Borders. Further guides to other groups of soil protozoa based on the same programme are envisaged. **Keith Vickerman**

BIRDS BY BEHAVIOUR
Dominic Couzens
Harper Collins, London 2003, 256 pp, softback, illustrated in colour throughout, ISBN 0 00 711549 0, £16.99

An interesting attempt at describing birds, for identification purposes, by their behaviour. The pages are packed with colour illustrations by several top class bird-artists. Completely without plumage descriptions, this book has set out to show characteristics on their own that will be useful for distinguishing one species from another. Has it achieved its aim? For the most part I'd say it has but there are a few anomalies with some rare birds included, but not others. For example, the flickering flight of the Common Sandpiper is described as "unique", although the American Spotted Sandpiper is identical in flight behaviour

and a regular scarce migrant in the UK, but American species are not covered. For birds at sea, the guide is really useful. But again a few notes are misleading – that European storm Petrels "regularly follow ships" is something I have never observed in years of being in ships and watching Storm Petrels. Gulls would probably kill them. And the "notched tail" of the Madeiran Storm Petrel is something hard to see even with the bird in the hand! There are also some fine points such as the stated size difference between Goldcrest and Firecrest that I find hard to accept as a good identification point. And the Wood Warbler positively shudders when giving out its distinctive call from the canopy but this isn't mentioned. Despite these criticisms the guide will prove a useful addition to the more normal field guides and I have no hesitation in recommending it to bird watchers both novice and experienced alike. **Bernard Zonfrillo**

PHOTOGRAPHING PLANTS AND FLOWERS

Paul Harcourt Davies

Collins & Brown, London, 2002. pp. 160 ISBN (hbk) 1-85585-930-0 Extensively illustrated with colour photographs, £17.99

Almost any problem you may encounter in photographing plants is covered in great detail in this profusely illustrated book. It is basically a manual that you can dip into for expert guidance on any topic. These include Exposure, all aspects of Lighting, Plant Communities, Plant Portraits, Trees, Close-up and Macro work, The Home Studio, Fungi and Image Manipulation on the computer. The headings are sub-divided with further categories giving yet more information. Plant photography abroad in extreme environments such as deserts, tropical forests and montane regions is included. Many useful photographic tips are found in all of these categories and the author's enthusiasm for plant photography emanates from every page. All of the pictures are accompanied with full details of the film, lenses, filters and exposures used.

The author writes a lot about the problems of using film at high altitudes, colour defects when photographing blue flowers and the effect of long exposures on colour values. There is, however, no mention what-so-ever of digital cameras which are now very popular with both amateur and professional photographers. The image sensors in digital cameras have a different spectral response to that of film and the above mentioned problems with are greatly reduced. The book would have been enhanced if this new imaging technology had been discussed. However, there is a useful but brief introduction to film scanning and printing using a computer and Photoshop imaging software at the end of the book. This book is a worthy addition to your personal library and is good value at the price.

T. Norman Tait

HOW TO IDENTIFY WEATHER

Storm Dunlop

HarperCollins, London, 2002, 192 pp, softback with many colour photographs and illustrations, ISBN 0 00 220202 6, £12.99

The eponymous author has written a most comprehensive yet compact text and, rightly in a book devoted to weather, avoids reference to climate or global warming. The text is liberally sprinkled with wonderfully clear photographs of most of the phenomena referred to. These photographs have been taken in many parts of the world, the polar regions, temperate regions, including Scotland, and the tropics. He explains in straightforward language the vagaries of the weather. Technical terms are certainly used but are clearly defined in the glossary.

The origins of weather and the way in which air masses move to form depressions and anti-cyclones are succinctly dealt with in association with clearly labelled diagrams of horizontal and vertical weather patterns. Whether referring to this text alone will actually help you to forecast tomorrow's weather in order to enable you to decide on the gear to carry on the Society's next outing is doubtful. TV forecasts are better for that. They get it wrong on occasion, however, and this book does provide the interested observer with enough background information to read the forecast maps critically and interpret the situation locally.

The list of sources of further information includes a number of relevant internet sites as well as books, journals and societies. This book is well worth its modest price tag. **Bob Gray**

THE NATIONAL PARKS AND OTHER WILD PLACES OF BRITAIN AND IRELAND

Jonathan Elphick and David Tipling

New Holland, London, 2002, 176 pp, hardback, many colour photographs, maps, select bibliography, index, ISBN 1 85974 898 8, £24.99

This is an easily read and well-presented book. Each area visited is illustrated with a map and there is a handy quick guide in argument form for each area. Notes on suitable clothing, the best time to visit, the requirement of permits, accommodation and non-natural history related activities are given. Included in the main text is information on birds, wildflowers, maritime and freshwater life, butterflies, moths, insects, geology, archaeology, climate as well as useful information on place-names and their derivation.

This book is suitable for the general reader and is ideal for those planning a holiday. It illustrates the diversity of wild life in Britain and Ireland and is a real "eye-opener".

This book is excellent value for money, however, as is noted, it was written prior to the Loch Lomond National Park coming into being and it is hoped that a chapter on this will be added should there be a second edition. **Margaret MH Lyth**

BIODIVERSITY: AN INTRODUCTION
Kevin J. Gaston and John I. Spicer
Blackwell Publishing, Oxford . Second Edition, 2004. Paperback.ISBN 1 4051 1857 1 (Paperback). Price £19.99

This second edition appears six years after the first, and Gaston and Spicer have made a substantial effort to update the reader with an introduction to biodiversity. In fact the book is more than an introduction *per se*. The main chapters cover the nature, history, spatial distribution, values, human impacts on, and maintenance of biodiversity. There is good literature coverage, supplemented with 'further reading' lists at the end of each chapter to help if an in depth enquiry is needed. The authors have also meticulously acknowledged the permission granted to reproduce the copyright material in figures and tables.

The earlier edition of this book had a more methodical beginning where biodiversity was defined first. However in this edition Gaston and Spicer begin with an example of Marion Island, one of the larger of the Prince Edward Islands group in the Southern Indian Ocean, and then define biodiversity. The first chapter then covers the different types of biodiversity, its hierarchal order, and species richness as the usual measure of biodiversity. The concept of nested hierarchy of biodiversity is an interesting one where bigger levels filter down to smaller levels (e.g. genetic diversity: populations, individuals, chromosomes, genes and nucleotides) and may be considered as analogous to a chemical compound, element, atom, electrons, protons, neutrons. Who knows? 'Chemodiversity' may become a future term in science. The authors quote in Figure 1.3 how two insect populations differ in biodiversity. A more logieal way of expressing biodiversity might be to compare two populations from different taxonomic groups of animals, because individuals in the same group are more closely related than individuals in different groups. The book goes into the intricacy of genetic diversity, but whether a general reader without any prior background understands this is debateable. For example 'The species with the greatest amount of DNA has about 100,000 times as much as that with the least, ...' would only be understood by the specialist.

The second chapter embarks on a temporal journey covering biodiversity, and its past, present and future structure. The authors consider the history of life, describing patterns of diversification and extinction. For example different modes of dispersal have promoted diversification in plants. The fossil record is one way of assessing the history of biodiversity, and here molecular information is increasingly becoming important in gauging biodiversity. An exciting notion is one of the *Hox* genes present in all organisms, which determine the diversity of body plan. Global, regional and local biodiversity relationships are discussed, with changing climatic conditions and the potential niches available to organisms. The former is an alarming threat in today's world of global warming (can we call this global warning!) and sea level rise, which has already started to cause habitat degradation and loss of biodiversity. Gaston and Spicer develop the model of mass extinction of different groups from a slow to a rapid diversification reaching a peak, and then a slow decline to extinction. A stasis state is reached when the rate of extinction equals that of speciation (adding species), and a state of decline takes place when the rate of extinction becomes greater than the rate of speciation. The average species-life span (time a species appears in the fossil record to the time it disappears) is between 5-10 Myr. For example coral reefs have an estimated mean duration of 25 Myr and primates 1 Myr. The authors go on to discuss factors such as intrinsic, extrinsic and environmental stresses, which may contribute to biodiversity decline.

How many extant species are there? As Gaston and Spicer point out, this very important question has no definite or easy answer. A number of extrapolation methods, based on expert information and well-studied habitats and groups have been used. An average estimate is 13.5 million species (with 3.5 a lower and 111.5 million an upper estimate). The lesser-studied groups (viruses, bacteria, protozoa, algae, nematodes and parasitic species) and habitats that harbour such groups, add to the uncertainty in numbers. It is estimated that approximately 1.75 million (13% of extant species) living species have been described so far, but there may be errors of homonymy and synonymy. The rate at which species are described is 13,000 species per annum, an average of 36 per day. By 2032, a figure of 247 more mammal species will have been described in addition to the 1992 total of 4628, and most of these will belong to orders Insectivora, Chiroptera and Rodentia.

In chapter three, Gaston and Spicer deal with the problem of mapping biodiversity. This includes spatial patterns and the distribution of both terrestrial and aquatic species. Surprisingly there is no complete count of all species for any geographical area – even for the smallest size area. Species–area relationships are explained from a sampling, habitat diversity, colonisation/extinction and speciation/extinction point of view. Differences between terrestrial and marine species diversity are caused by five main factors – life originated in the sea, terrestrial environments are more heterogeneous than marine ones, the sea-bed is less variable than the terrestrial environment, land and sea herbivore patterns differ, and there are differences in the body size distributions of terrestrial and marine species assemblages. Marine biodiversity is highest in the Indo-western Pacific, and both terrestrial and marine species richness decreases from tropical to temperate latitudes. Freshwater systems are less well documented, with 70,000 species described and an assumed 100,000 awaiting discovery. The authors classify biogeographic regions on land and identify tropical

regions as the major habitats, based on vegetation type and biomass. More countries have species data on mammals than on flowering plants. Our attention is drawn to the 25 biodiversity hotspots with the highest concentration of endemic species, which are threatened by habitat loss. Marine biogeographic regions are difficult to divide owing to sharp floral and faunal discontinuities, and to the huge extent and the 3-dimensional complexity of marine ecosystems. Some methods are based on algal ecology of the pelagic open ocean and others on biogeochemical features. The former method is not convincing to the current reviewers, because the pelagic zone can extend much deeper than the realm of algal growth in the euphotic zone (100-150m).

The lead questions in chapter four are "Does biodiversity matter?" or "what value is biodiversity to us?". Gaston and Spicer highlight the use and non-use values of biodiversity. The uses can be direct (food, medicine, biological control, industrial, recreational and ecotourism) and indirect (atmospheric, climatic, hydrological, nutrient, pesticide, photosynthesis, pollination, soil formation). Under the non-use values the authors list the option value, bequest value, existence value and intrinsic value, where most of these are related to posterity.

Chapter five considers human impacts on biodiversity, and is new to this edition. The authors acknowledge that man's colonisation of some regions of the world has contributed to biodiversity loss – and this is fairly self-evident. The main causes are direct exploitation, habitat loss, degradation, and fragmentation, and introduction of alien species. Extinction cascades may happen when the extinction of one species leads to the extinction of others. As human population growth rises the percentage of habitat loss, and therefore biodiversity loss, increases.

The final chapter six, which was the final chapter (chapter five) in the first edition, includes ways of maintaining biodiversity. Gaston and Spicer describe the Convention on Biological Diversity (CBD) and its responsibility to conserve biodiversity with its 42 Articles, together with the concept of sustainable use as the core. Article 1 of the CBD defines the objective of the convention, which encompasses the conservation of biological diversity, its sustainable use and the fair and equitable sharing of the benefits from the use of genetic resources. The latter is a stark reminder that in the past some nations have exploited the genetic resource of others without recompense. The authors then identify Article 6 of the CBD as 'the most far-reaching and significant' one, which calls on each contracting party to develop and integrate national strategies and programmes for the conservation and sustainable use of biodiversity. As a result, a number of nations have developed National Biodiversity Strategies and Action Plans. Action Plans are the documents which outline how societies propose to re-structure lifestyles towards conserving and sustainable use of biodiversity. The overall goal of the UK Action Plan is 'to conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all appropriate mechanisms'. Some of the Articles listed have the following goals, Article 7 (identify and monitor), Article 8 (*in-situ* conservation), Article 9 (*ex-situ* conservation), Article 10 (sustainable use of the components of biodiversity) and Article 11 (incentive measures). An important point associated with *in situ* conservation in Article 8 is highlighted by oversight or neglect, which may result in 'paper parks'. These are areas formally designated for conservation but which receive limited or no protection. For example the world's largest colony of arctic terns was present in a Ramsar wetland site in Iceland, but due to no practical significance of this site it led to the loss of all breeding pairs of the terns in 2000. As Gaston and Spicer point out, it is easy for nations to produce Biodiversity Strategies and Action Plans, but implementing the strategy to effectively conserve biodiversity and its sustainable use is a difficult challenge. We personally have first-hand experience from our work in developing countries of the difficulty of non-implementation of policies. The extent to which the principles of the CBD can be achieved will determine the progress of nations towards sustainable conservation of biodiversity.

A few examples in the book may prove slightly too technical for a non-specialist reader. In some cases legends to figures are not fully explanatory. For example in Figs. 6.1 and 6.2 the reader is left to ponder whether the graphic data is global, national or regional. If Gaston and Spicer intend to publish a third edition, black and white or coloured photographs of different environments would add to the appeal of the book. A section on biodiversity in extreme environments would also be valuable.

To summarise, the authors have amassed an excellent collection of literature related to biodiversity and conservation and a number of good examples to illustrate the threats facing biodiversity and its potential loss. This book is an excellent basic introduction to general biodiversity for students and teachers, as well as generalists and amateurs interested in exploring the fundamentals, uses, threats and conservation of biodiversity.

Azra Meadows

TARNS OF THE CENTRAL LAKE DISTRICT
Elizabeth Haworth, George de Boer, Ian Evans, Henry Osmaston, Winifred Pennington, Alan Smith, Philip Storey, Brian Ware.

Brathay Exploration Group Trust 2003: Ambleside, Cumbria, 204pp. ISBN 0 90601517 0

The Brathay Hall Trust is a highly respected educational charity that has provided over 50 years of excellent youth work from its base in Ambleside. Early on it recognised the immense value of exploration and adventure in developing the full potential of young people. Concurrently the

science of glaciology was really taking off, and one of the Trusts earliest projects was the ambitious and challenging task of surveying a variety of tarns throughout the Lake District. Thus the Brathay Exploration Group (BEG) was born, and today over 10,000 people have benefited from participation in over 650 of its expeditions worldwide.

This book is the culmination of over 50 years of voluntary research and labour and you really get a feel for the tremendous effort that has taken place. Pictures of schoolchildren portaging boats and heavy equipment through arduous mountainous terrain (p.47) or precariously rowing very flimsy folding boats (p.49) illustrate what the somewhat dry scientific style of prose can only hint at. Indeed the production of the book itself was a fine endeavour and the editor confides of the exasperation that he felt that so much work might be unpublished given the vast amount of data and decades of differing researchers.

The style of the book is appropriate with an engaging discussion in Part One and detailed examination in Part Two. Part One comprises chapters on the 'geology and tarns of Lakeland'; 'Lakeland tarns, cirques and glaciation'; 'evidence from the tarns of vegetation, soils, climate, and human settlement'; and finally 'the history of lateglacial and postglacial changes in the tarns'. Each chapter is written by a respected author in his or her own field, with many senior scientists from the Freshwater Biological Association involved, and taken together is a valuable review of Lakeland natural history and it's wider environmental and historical context. As an ecologist I was surprised to find how interesting the story of tarn formation was, although I still prefer the term 'corrie' to 'cirque' even if the author disapproves! The solving of the controversy over rotational cirque glaciation was in part due to BEG work where imaginative studies with Helium balloons showed how certain glaciers could be made to rotate by action of the prevailing winds. That combined with the BEG soundings that recorded the extraordinary depth (63m) of Blea Water, attested that only a rotating glacier could have scoured such an impressive feature.

Part Two is a description of the survey and cartography work, followed by a detailed examination of 50 Lakeland water bodies. Each tarn has a separate entry comprising a standardised bathymetric chart, with accompanying statistics and description of its geology, geomorphology, ecology and historical context. This format is easy to use as a ready form of reference (birders, botanists and anglers alike will appreciate the information) and given its broad approach everyone will be able to find little gems of interest, from comical one-liners about the fieldwork ("a 70mph gust of wind caused the boat to sink" - p.153) to new facts (a 'schwingmoor' is a bog floating over water - p.119). My one minor criticism is, that although the individual tarn maps are well produced, it would not be easy to picture their wider context without looking at the relevant OS map (this is aided by the grid reference provided). I assume copyright forbade this added luxury. To be fair, over half the tarns (mostly the ones far from the tourist trail) have a colour photograph which gets over this problem. Furthermore each tarn should have been numbered and cross referenced with the Lake District map in the front cover, as the diagram on page 12, which attempts this, is very difficult to read.

The photographs and illustrations are generally of a high standard. The best are a stunning vista of Bleaberry Tarn (p.8) and the beautiful SEM photographs of diatoms (p.140). The disparity between the two should give some indication of the broad appeal of this book. The BEG have done similar long-term studies on Foula, which I look forward to being published. In the mean time I didn't realise that small freshwater bodies could have so much interest, and this would be a good read for any natural historian fond of the area or as a reference for a future visit. This book is available at brathayexporation.org.uk (£12 + £2.50 postage).

Daniel Gates

NIKO'S NATURE: A LIFE OF NIKO TINBERGEN AND HIS SCIENCE OF ANIMAL BEHAVIOUR.
Hans Kruuk.

Oxford University Press, 2003. 391pp. £20 Hbk ISBN 0-19-851558-8

To a public obsessed with the private lives of so-called celebrities, the lives of naturalists set down in print may seem rather dull. To fellow naturalists, however, they may carry some lesson or message and Hans Kruuk's beautifully written-memoir of his mentor, the great naturalist Nikolaas Tinbergen (1907-1988), certainly does this. The "Nature" of the title refers to both the object of Tinbergen's life's work and the nature of the man himself.

In the mid twentieth century this modest Dutchman along with his more extrovert German correspondent, Konrad Lorenz, transformed the study of animal behaviour and created the new science of ethology, with profound repercussions for psychology, ecology and much else. Before that, it had seemed that the only way to study behaviour scientifically was through experimental intervention - by presenting a contrived stimulus and then recording what the animal did. Tinbergen insisted that there is no point in studying contrived behaviour unless we know beforehand the norm from which the variants depart. He emphasised the importance of observing behaviour in the animal's natural surroundings and was critical of psychologists who studied behaviour in artificial laboratory environments. Only when the context and natural behavioural repertoire of a species had been established was it possible to begin experimental investigation of the causation, development and survival value of behaviour patterns, and to reconstruct their evolution. These

four aspects of behavioural studies formed the backbone of his science of ethology which sought to rid the study of animal behaviour of all traces of anthropomorphism. and combine functional and causal explanations. Ethology came of age in 1973 when Tinbergen, much to his surprise, was awarded the Nobel Prize for Physiology or Medicine, along with Lorenz and Karl von Frisch, the discoverer of communication by dance in honey bees.

From his boyhood in the Netherlands, Tinbergen had been passionate about watching animals in nature (in this he differed from Lorenz who had a passion for observing household pets!). Kruuk charts his undergraduate studies in biology at Leiden University, his postgraduate studies of homing in digger wasps, his 14-month honeymoon expedition to Greenland studying arctic bird behaviour, and his subsequent lectureship at Leiden. Tinbergen's early work was concerned mainly with causation - the internal (motivation) and external factors causing behaviour in particular species, most notably in the courtship behaviour of the three-spined stickleback and in the bill-pecking response of newly-hatched herring gull chicks to elicit food regurgitation by the parent gull. The stickleback was ideal for simple experiments as its natural environment could easily be imitated in an aquarium tank, and Tinbergen was able to analyse the stimuli provoking attack and courtship from a territory-owning male. To naturalists, the red belly of the male stickleback and the red spot on the bill of the parent gull became famous as sign stimuli or "releasers".

After the war and a move from Leiden to Oxford University in 1949, Tinbergen became more preoccupied with functional (survival value) explanations and the evolution of behaviour. But first he published three important classics drawing heavily on his work till then. After *The Study of Instinct* (1951) came *Social Behaviour in Animals* (1953), the latter written largely while he was incarcerated by the Germans during World War II. *The Herring Gull's World* (1953) published in the Collins *New Naturalist* Series remained in print for nearly thirty years. These books established his reputation in the English-speaking world.

In Oxford, with many students and collaborators, he greatly expanded his gull behaviour research with emphasis on the evolution of the various signals of the different species. The function of each signal was deduced from observing what other birds did immediately after the signal was given, for example grass pulling by one gull caused nearby gulls to move away. Although as a student he had spurned comparative anatomy, he essentially applied its principles to reconstructing the evolution of gull signals and demonstrating how in "ritualization" natural selection operates to transform a behaviour pattern into a more reliable form of communication. A keen photographer, the results of this study were made into an award-winning film and a book with the same title - "*Signals for Survival*" (1967). Alongside his photographic skills, Tinbergen was also a talented artist and his sketches and photographs add considerable charm to Kruuk's book.

So much for the Nature that Tinbergen adored - what about the nature of the man himself? Alas, the downside of Tinbergen's love of observing Nature was a deep-seated feeling of guilt. Like most academic family men, he felt guilty about the neglect of wife and children that his devotion to research occasioned. But in addition, steeped in the Protestant Work Ethic (despite his agnostic views he had a strong Calvinist background), he felt guilty about being paid for doing what he enjoyed most in life - observing Nature. Now I suspect that most university professors regard their salaries as derisory compensation for the teaching and administration they are called upon to do, and view any enjoyment of their research as some compensation for their paltry pay; but not Tinbergen, apparently - despite his acknowledged excellence as a teacher. And was it also a feeling of guilt about accepting the Nobel Prize for Medicine that made him devote his speech at the award ceremony in Stockholm not to what sticklebacks and sea gulls have taught us but to the problem of autism in children (an interest of his wife's) and to the somewhat irrational Alexander Technique for improving human posture (successfully applied, he believed, to his daughter)? The decision was a mistake. Lead balloons descended!

His love of Nature brought Tinbergen high academic honours and his science of ethology was wondrously seminal for it opened up new approaches - sociobiology and behavioural ecology to name but two. Yet, with touching sympathy, Kruuk relates how his last years were spent not basking in the glory of being the "grand old man" of his subject but tinged with depression and despair over the future of humanity. The lesson of this insightful biography to all naturalists is clear. Enjoy observing Nature - but do not feel guilty over doing so! **Keith Vickerman**

COLLINS WILDLIFE TRUST GUIDE TO THE WEATHER OF BRITAIN AND EUROPE
David M Ludlum

HarperCollins, London, 2001, 664 pp, includes 389 full colour photographs, soft all-weather cover, ISBN 0 00 220138 0, £16.99

We are all dependent on the weather whether we wish to climb Cairngorm, weed the garden or do a bit of sunbathing. Although, perhaps like me, you are not quite certain what the weather forecaster means when they talk of an occluded front moving in – then this is the book for you! There is a multitude of diagrams and descriptions to explain weather terminology and systems.

Most weather forecasters talk about the West of Scotland, Southern England etc. But with this book you can produce your own local forecast. There are easily understood examples on how to produce your own forecast by using diagrams, text and coloured

photographs. The 389 coloured photographs are of excellent quality.
It is a highly recommended buy, which can be conveniently used outdoors in all weather conditions. An additional reason for purchasing this book is that Collins make a donation to the Wildlife Trusts for each copy of the book that is sold.

Ian C McCallum

FOSSILS AT A GLANCE
Clare Milsom and Sue Rigby

Blackwell Publishing, Oxford, 2004, 155 pp, softback, numerous diagrams and drawings, ISBN 0 632 06047 6, £19.99

A book for students. The introduction explains that a glance may be made at a double-page spread for illustrations. The illustrations number four per page, over a hundred fossils altogether. A hundred more are named in the text, which presents a generalised view of palaeontology as a whole, rather more than the title suggests. It is a very concise and fairly up-to-date view, suitable for students revising for examinations, but will also be used as a reference, as emphasis is placed on the vocabulary used to describe fossils. The illustrations have all been specially redrawn from published sources. For no good reason these are acknowledged picture by picture instead of being listed by source. Some are not improved by the artist who is not named. The insect has impossible wing venation. Composition and layout are not as well suited to the printed page as they should be using a computer. The results are a trifle amateur in this case.

J. Jocelyn

CASSELL'S TREES OF BRITAIN & NORTHERN EUROPE
David More (author) and John White (artist)

Cassell, imprint of Weidenfeld & Nicolson, London, 2003, 800 pp, hardback with many coloured illustrations, ISBN 0 304 36192 5, £50

The huge number of introductions from overseas more than makes up for the lack of native trees in Europe compared to other continents. Nowhere is the climate at these latitudes better for the growth of trees than in the British Isles, which explains the huge number of non-native species described in this sizeable work.
The introduction details the history of introductions to the British Isles as well as giving planting hints and listing tree choices for different habitats. Towards the end is a section devoted to illustrations of winter twigs, not commonly found in books of this type, but extremely useful for winter identification. Not that this tome could be used in the field; but it is more than a coffee table decoration. It is full of intriguing and detailed information about trees that will more than satisfy the most ardent searcher for detail. Having said this, although the tree sequence is broadly the conventional scientific order, the text is of general rather than detailed botanical interest. The book contains an impressively large number of descriptions of cultivars of each species, e.g. 24 cultivars of yew, 30 of beech and even the oak *Quercus rubra* has 13 described. Flowers, fruits, leaves, winter twigs, bark and silhouettes are meticulously drawn for species. The mostly very accurate illustrations have clearly been drawn from real life specimens as indicated by the imperfections found in plant structures caused by things such as insect damage. The large number of written and illustrated descriptions explains the considerable size of this book. However, the quantity of these descriptions does mean that the number of cultivars, sub-species and varieties that can be dealt with is limited by means of space and this is arguably the main drawback associated with a book such as this. One could also debate the use of certain biological names. Nonetheless, White and More have created a work of great balance between text and illustration and the detail provided is more than adequate for all but the most demanding of readers.
This book would form a valuable addition to the library of any tree enthusiast.

Bob Gray

THE GARDEN BIRD HANDBOOK
Stephen Moss

New Holland Publishers (UK) Ltd. London published in association with The Wildlife Trusts, 2003, 160 pp, 250 colour illustrations, 130 colour photos. ISBN 1 84330 124 5, £16.99

Stephen Moss has done a sterling job in producing this garden book handbook for The Wildlife Trusts. The content of the book is comprehensively set out and this reviewer cannot think of any aspect of garden birding lacking in the information and ideas presented. Here we have suggestions on creating a garden fit for birds, to understanding garden birds and their behaviour. The chapter on 'The Garden Bird Year' is a great help to those who are unsure which species to look out for or which action to take to ensure that birds thrive throughout the year. Fifty species most likely to be attracted to gardens are illustrated with an informative passage on each. The book is beautifully illustrated throughout with both artwork and photographs. I admit to initially thinking that this book would be of interest only to those with large gardens and time and money to spare, but the section on 'The Basic Bird Garden' dispelled that idea. A garden, however small, is a haven for birds. A very little amount of time and cash spent on thoughtfully attracting birds to any garden enhances their survival enormously and gives a great deal of pleasure to the owner.

Joyce Alexander

BILL ODDIE'S INTRODUCTION TO BIRDWATCHING
Bill Oddie

New Holland Publishers (UK) Ltd., London, published in association with Wildlife Trusts, 2002, 144 pp, hardback with illustrations by David Daly

(artist) and David Cottridge (photographer). ISBN 1 85974 894 (hardback) 1 84330 016 8 (paperback), £12.99

Those who have enjoyed Bill Oddie's refreshing, humorous, down to earth, observant and well-informed TV presentations will find the style reflected in this concise little book form the Wildlife Trusts. It is not a field guide as such but fulfils its role as a "perfect book for novice birdwatchers", while more experienced readers will enjoy its style and matter – above all practical: "...go & do it!". Information sources, choice of equipment, basics of identification, bird behaviour and songs, finding them, twitching, bird reserves and conservation are presented simply with leads to broader aspects and the practical use of collected data – even "birds in cyberspace", bird organisations and more advanced reading are concisely presented. The light-hearted text is supported by appropriate, attractive illustrations to illustrate the "jizz" and context of birds.

Norman R Grist

THE NEW ENCYCLOPEDIA OF INSECTS AND THEIR ALLIES

Christopher O'Toole (Ed)

Oxford University Press, Oxford, 2002, 240 pp, hardback with numerous colour photographs and illustrations. ISBN 0 19 852505 2, £25

At first sight this lavishly produced large format publication might be assumed to be another picture book primarily destined for the coffee table. Nothing, however, could be further from the truth, for the text, written by a team of scientists, each expert in his or her own field, is concise, authoritative and informative. This is supported by many coloured photographs, drawings and diagrams of superlative quality which feature species from all over the world.

Starting with general accounts of the structure, physiology and versatility of arthropods the book proceeds to treat each group in detail. Myriapods, including less well-known forms such as pauropods and symphylids, hexapods, including insects, and arachnida are dealt with in turn. Crustacea, apart from brief mention, are not considered.

The distinguishing and biological characteristics of each group are discussed in detail and the main text is supported by "factfile" summaries of classification and items of special interest such as chemical defences in bombardier beetles, territoriality, mating and sperm competition in dragonflies and the jumping of fleas. At appropriate points more extended accounts deal with subjects such as the importance of honey bees to Man and flowering plants and the growing utilisation of solitary bees as pollinators in farm practice. Web building in spiders is described in detail. The book ends with an extensive glossary, a bibliography and a comprehensive index.

Despite its general excellence the book has some faults. Apart from the ubiquitous use of Americanisms, deplorable in a British book, some thirty-four spelling mistakes were detected in a single reading. Also there were more than a few factual errors e.g. lycaenids are not beetles (p 26 and index p 231); Sternorrhyncha are defined as aphids but later Aleyrododiea, Coccoidea and Psylloidea are added (p 87); the tibia is omitted from a list of insect leg parts (p 225); insect tracheoles are very much finer than 0.1 mm (p 24); mosquitoes are not vectors of smallpox (personal communication, Professor NR Grist) (p 144) and smallpox, indexed for p 128 does not appear on that page. Referring to Apocrita, it is stated that in the larvae the mid-gut and hind-gut are not united until the larval stage (p 172). The termite (Fig. 3, p54) is a soldier not a worker.

Despite these defects, which ought to be corrected in a second edition, the book is strongly recommended for serious naturalists and for students who want to add meat to the bare bones of their textbook accounts. **Ronald M Dobson**

WILD SIDE OF TOWN: GETTING TO KNOW THE WILDLIFE IN OUR TOWNS AND CITIES

Chris Packham

New Holland, London, 2003, 144 pp, hardback with numerous colour photographs and colour illustrations, bibl., ISBN 1 84330 355 8 £16.99

Although this book is well written in a light and entertaining style, it is extremely thought provoking. Are, for example, we keeping our homes and towns too clean and so having an adverse effect on wildlife? Is it not sad that man, through changes in farming methods and his intolerance to starlings roosting in towns, has contributed to a 65 per cent decline in starling numbers since 1969?

The activities of the urban fox are noted, including its ability to dine on anything from pizza to kebabs, however, the author claims that foxes do not attack cats, a statement which is doubtful as I have witnessed a domestic cat being mesmerised by a fox, disaster for the cat only being prevented by my intervention.

This book is beautifully illustrated by photographs of a high quality. There is a useful field guide which is well illustrated. There is a glossary and a directory to the top urban sites of local Wildlife Trusts. The book has an index, is good value for money and is an excellent eye-opener for both the urban dweller and visitor. **Margaret MH Lyth**

WINDERMERE – RESTORING THE HEALTH OF ENGLAND'S LARGEST LAKE

AD Pickering

Freshwater Biological Association, Ambleside, UK, 2001, 126 pp, softback, many colour photographs, maps and diagrams, ISBN 0 900386 68 1, £10

The title of this volume would suggest that its focus would be on managing the effects of man on a large lake. In fact, it is much more than that. Written in a style and format that is highly accessible to any with only minimal natural history knowledge, this

book begins at the very beginning for Lake Windermere. Informed by some of the most extensive and long-term studies conducted in any freshwater lake, the author covers, in an informative but simple style, the geological and glacial formation of the lake, its physio-chemical structure and the main groups of plants and animals that live there. In the second half of the book, the focus is on informing the reader of the scale, scope and history of man's influence on Windermere and on the science behind how some of these changes are now being reversed. The author, a research scientist with very considerable experience, delivers the account with clarity and authority and has achieved the difficult balance between the technical and the popular. This volume should be of interest to all with an interest in our aquatic environment.

Colin Adams

KEYS OF LARVAE AND JUVENILE STAGES OF COARSE FISHES FROM FRESH WATERS IN THE BRITISH ISLES
AC Pinder

Freshwater Biological Association Scientific Publication No 60, Freshwater Biological Association, Ambleside, UK, 2001, 136 pp, softback, colour photographs and line drawings, ISBN 0 900386 67 3, £20

For practical ecologists studying plants and animals from samples taken from the wild, one of the major problems has always been that the organism that you are trying to identify does not "fit the key", thus leaving some doubt about its identity. One of the reasons for this is that the vast majority of keys were developed for specific life stages: usually adults or at least well-developed juveniles for animals. This is particularly true of the fishes, so much so that the field ecology of sub-adults has been, to a large extent, a neglected area of study; for how can you base sound science on organisms that you cannot identify with some certainty? This volume, number 60 in the world leading FBA Scientific series, is a highly authoritative attempt to provide the tools through which field ecologists working on fishes may start to work with some confidence on juvenile stages of freshwater fish species. The key covers 26 freshwater fish species (defined as species that spawn in freshwater) but excluding those species belonging to three families closely related to the salmonid group (the whitefishes, the trout and salmon and the grayling). Because the development process changes identification characteristics (a problem that has dogged previous attempts at identification keys for sub-adults), by necessity, the author has had to develop separate keys for different life stages. Thus, an initial key guides the reader to a set of definitions of life history stages used in the key, which in turn allows identification from one of 5 keys for free embryos, young larvae, intermediate larvae, older larvae or young juveniles. One of the difficulties facing development of this type of key is that of the possibility of interspecies hybrids being inadvertently used to describe characteristics. To avoid this, the majority of the keys were constructed from captive hatched young of known parentage. Including both informative line drawings and colour photographs, this volume provides both literal and metaphorical keys unlocking the field study of sub-adult freshwater fishes in the UK. No group working on the field ecology of freshwater fishes will be without a copy.

Colin Adams

LAKELAND
Derek Ratcliffe

New Naturalist No. 92, Harper Collins, London 2002, 384 pp, with 43 colour plates and over 130 black & white illustrations. ISBN 000 711303 X £34.99 (hardback), 000 711304 8 £19.99 (softback)

With a similar sounding title to one already published in the 'New Naturalist' series (i.e. 'The Lake District' by Pearsall & Pennington 1973, which was restricted in its coverage to the National Park), it is understandable that comparisons may be made. But this would be a mistake, as the two volumes adopt quite different approaches to this outstanding part of Britain and compliment one another.

In defining the boundaries of his study area, Dr Ratcliffe has looked much further back than the establishment of the National Park 1951; in fact to the classis work 'A Vertebrate Fauna of Lakeland' (Macpherson 1892) which took in the entire former counties of Cumbernauld and Westmoreland. Right from the start the present author acknowledges and describes the invaluable pioneering work undertaken by long-gone naturalists, before presenting an up-to-date account of the wildlife of the region, much of the information included gained from personal experience over many years. All habitats and their special species are thoroughly covered, but it will come as no surprise to many that it is in the uplands where his heart really lies.

These days 'New Naturalist' books remain in print for a remarkably short period of time, so my advice is that you obtain your own copy of this authoritative and highly readable publication whiles stocks last.` **John Mitchell**

ATLAS OF CETACEAN DISTRIBTION IN NORTH WEST EUROPEAN WATERS
James B Reid, Peter GH Evans and Simon P Northridge

Joint Nature Conservation Committee, Peterborough 2003, 75 pp. Softback, pictures and maps in colour, ISBN 1 86107 550 2, £17 plus postage & packing. Available from Natural History Book Service Ltd., 2-3 Wills Road, Totnes, Devon TQ9 5XN

Complied from a database of many years (about twenty) of recording Cetaceans in European waters, this atlas represents an up-to-date picture of where some of the most enigmatic sea mammals can be expected to occur. There are useful descriptions of the marine environment of various parts of the coast

and some maps showing currents and sub-sea "fronts" that most of us will know little about. The actual maps are in three forms – each adapted to the regularity of observation and relative abundance with a final method of rarities – mainly "one-off" observations.

Some species seem under-recorded but this is perhaps to be expected. People are now taking a general interest in whale watching that did not previously exist. At a more local level, in recent years the Minke Whale, one with a calf, has been seen in summer in the Firth of Clyde and there has even been a stranding or two, but these are not mapped or mentioned.

The atlas will help build a picture of the true distribution of Cetaceans around our coasts. If this atlas does one thing it will no doubt inspire naturalists to get out to coasts and headlands with telescopes and get into boats and go see for themselves these fascinating creatures. Anyone who ventures near the sea should have a copy of this Cetacean atlas. **Bernard Zonfrillo**

THE PHYTOPLANKTON OF WINDERMERE (English Lake District)
CS Reynolds and AE Irish

Freshwater Biological Association, Ambleside, UK. Special publication 2000, 73 pp. Softback: colour photographs, charts and diagrams. ISBN 0 900386 65 7, £20

The Freshwater Biological Association has played a pivotal role in the development of the understanding of processes and patterns in freshwater ecology over the last seventy years. It is true to say that its publications over this time had a major influence on almost every aspect of freshwater ecology. This latest publication continues in this tradition. Highly authoritative, this short (73 pp) volume summary by highly respected limnologists pulls together into a single source, fifty years of study into the seasonal and spatial dynamics of phytoplankton from Lake Windermere. In addition to their dynamics, Windermere catchment hydrology, the effects of a water quality restoration programme and the role of phytoplankton in the ecosystem are covered. As a case study of this fascinating group and mans' impact upon it over time, the long-term monitoring described in this work must be unrivalled anywhere. The descriptions of the results of these studies are clear, concise and also well referenced and accessible by any with some basic knowledge of aquatic systems. It is clear that this volume will act as a source book for teaching material at senior secondary and undergraduate level for the next decade. **Colin Adams**

PEOPLE AND WOODS IN SCOTLAND, A HISTORY
Edited by TC Smout

Edinburgh University Press 2002. 244 pp numerous maps, photos and drawings, 8 pp in colour. ISBN 0 7486 1700 0 £45 (hardback), 0 7486 1701 9 £14.99 (softback)

Scotland's woods and peoples have been inextricably linked since the end of the Devensian glaciation. Most likely trees and people colonised the land together and their association continues to the present day with each having influenced the other throughout the millennia. Woods provided a habitat for animals popularly hunted by early peoples. They provided, and continue to provide, edible fungi. Their timbers have been used for many types of building, for furniture, for carvings and for export. They have inspired out poets and added to our culture. Today we can take added pleasure in our woodlands by pursuing a variety of outdoor activities, whether this be for exercise or relaxation.

'People and Woods in Scotland', commissioned by the Forestry Commission, marries Scotland's woods with her people. Christopher Smout has edited the book and written an interesting and wide-ranging introduction. The twelve contributors are to be commended for their prodigious research. Scotland has been well served by their erudite but readable essays which range chronologically from 11,500 years ago to the present day and beyond, the last essay predicting that diversity will most likely be the key to the future of our woodlands.

The text is complemented throughout by many black and white photographic illustrations though several of those are too dark to be seen clearly, as is the case with some of the colour plates. Also, please note that Ayr and Wigton are on the west coast and not the east coast as stated on page 78. That aside this book is greatly to be commended for the knowledge we gain from it about the history of our woods and people. The Forestry Commission must indeed be pleased with the result.

Joyce Alxander

THE STORY OF LIFE
Richard Southwood

Oxford University Press, Oxford, 2003, 264 pp., hardback with line drawings and tables. ISBN 0 19 852590 7, £ 19.99

This book, by one of the acknowledged giants of biology, is a work of considerable scholarship and erudition. In a series of 12 chapters it reviews the whole spectrum of life from its origins, based on simple organic molecules synthesized on earth or derived from bombardment by galactic bodies, to the most sophisticated organisms of the present day. The text is clear, largely untechnical and, considering its broad scope, remarkably compact.

The work bears many similarities to the recent Variety of Life by Colin Tudge (Oxford University Press, 2000 - reviewed in The Glasgow Naturalist, Vol.. 23 Pt.5, 2000 - but there are significant differences and the two should be regarded as complementary rather than competitive. Tudge reviews the whole range and interrelationships of animals and plants whereas Southwood's account in this respect is less detailed but is more concerned

with general biology and evolution as shown by the fossil record.

Topics such as the movement of tectonic plates and the influence of these on climate and organisms and the reasons for mass extinctions, such as that which occurred at the Cretaceous/Tertiary interface are considered in detail as are the effects of fluctuations in the proportions of atmospheric oxygen and carbon dioxide.

Amongst numerous other topics there is an interesting chapter on dinosaurs and another on the inhabitants of sand, mud and shallow seas in relation to the evolution of fish and the eventual emergence of terrestrial forms with all the anatomical and physiological adaptations that this entailed.

The penultimate chapter deals with the evolution of the primates eventually leading to man and finally there is an account of man's influence on the environment from his beginnings as a hunter/gatherer to his present-day dominance and, arguably, lack of responsibility.

Errors are few and are mainly typographical rather than factual, e.g. incorrectly hyphenated words appear occasionally and there are a few oddities, e.g. "trachaeae" instead of "tracheae" (p. 100) and, referring to Paranthropus, "goisei" (p. 219) and "bosei" (p. 222) rather than "boisei". The abdominal feet of caterpillars have "crochets", not "crotches" (p. 105) and the extinct sea-cow was named after "Steller" not "Stellar" (p. 237). Such slips are of little consequence however and the book is highly recommended to both scholars and laymen. **Ronald M. Dobson**

BRITAIN'S BUTTERFILES
David Tomlison and Rob Still

Wildguides Ltd., Old Basing, Hampshire, 2002, 192 pp. Softback, numerous full-page colour photographs. ISBN 1 903657 01 6 £15

Yet another book on British Butterflies but this one genuinely attempts to be different. All the "60 regularly occurring species" in Britain and Ireland are illustrated by an electronically blended montage of colour photographs, from nature, of the various life stages of each species on the same plate. Thus egg, caterpillar, chrysalis and adult are depicted side by side for each species. Although such a juxtaposition of stages is artificial and will offend the purists it is surprisingly successful at giving a rounded view of the speeies. In most cases the larval food-plant is used as a backdrop. The life cycle montages illustrate caterpillar, chrysalis and adult at $1^1/_2$ fold enlargement and as both sexes of the adults are shown in their natural wings-open and wings-closed resting postures it makes an ideal butterfly identification guide for use in the field. The strong flexible binding also favours this. The montages would be difficult to use in the identification of the cryptic coloured caterpillars; to cater for this the individual life-size pictures of the caterpillars are brought together in a special section at the end - likewise the chrysalises (not chrysalis) and eggs, although the latter are at 10-fold magnification.

The illustrations are backed up by concise clear text on identification, behaviour, habitat and status for each species, along with a colour-coded life-cycle chart and a distribution map. No book is ever totally error-free but this one gets very close, although a Large White chrysalis masquerading as a Marbled White on page 12 is a disappointing slip. Introductory chapters on biology, taxonomy, habitats, gardening, observation technique and conservation make this a well-rounded and worthwhile purchase. My only complaint is that by sticking rigidly to photographs of natural resting postures the reader is left in ignorance of the colour pattern of the upperside of the Wood Whites, Brimstone and some of the Hairstreaks, which always close their wings together at rest!

KP Bland

KEYS TO THE CASE-BEARING CADDIS LARVAE OF BRITAIN & IRELAND
ID Wallace, B Wallace and the late GN Philipson

Freshwater Biological Association Publication No. 61, Ambleside, 2003, 259 pp. Softback numerous line drawings. ISBN 0 900386 70 3 £22.

This is the third publication from the Freshwater Biological Association on caddis fly larvae. Their inherent interest to naturalists and biologists, based mainly on behavioural aspects of their case making, means that the latest one is already out of print even though it was produced in 1990. In addition to the features commented on favourably in the review of that edition (*Glasgow Naturalist* **22**(1): 10) a number of improvements have been made. Each family with its own general account and integral keys to species has expanded notes on ecology and distribution. Any feedback on problems encountered by users has been dealt with by using more diagrams and the whole is generally more user-friendly. A section highlights areas of difficulty and gives advice on over-coming them. There has been some advance in the treatment of the family Hydroptilidae which now includes details for more species of these tiny caddis flies. Despite their size the case construction is still remarkable for its architecture, which is only constructed during the final instar, earlier stages being free-living. It is just that one needs s microscope to appreciate it. **EG Hancock**

TRAVELLERS' NATURE GUIDES
Britain by Marin and Bob Gibbons, Scotland text by Kenny Taylor, France and Greece by Bob Gibbons

Oxford University Press 2003. Britain 373 pp, softback, ISBN 0 19850433 0 £14.99. France 334 pp, softback, ISBN 0 19 850431 4 £14.99. Greece 315 pp, softback, ISBN 0 19 850437 3 £14.99

Each illustrated with colour photographs of habitats and some individual species, line drawings of plants, birds and insects, and maps of regions

showing distribution of sites and some detailed maps.
These guides will be useful to the independent traveller, who should study the one dealing with the country of choice before making up his itinerary. The contents of each guide are arranged in a similar way – namely on overview of the country, dealing with aspects such as geography, geology, climate, vegetation and habitats, followed by a very detailed account of the best locations for wildlife, usually in National Parks or Nature Reserves. There is sometimes a section dealing with access and route finding, although not in the guide for France. The chapter on Nature Conservation does point out that although in Britain we have poorer flora and fauna than in the rest of Europe due to the effects of the Ice Ages, we do have a more effective system of conserving what we have. In the books on France and Greece there are suggestions for further reading. In each book a map shows how the country has been divided into large areas, which are then subdivided into regions or countries. In the book on Britain, for example Scotland is divided into eighteen regions such as the Flows and North Mainland, Torridon and Applecross and the Cairngorms. Under the heading of Cairngorms, the chapter mentions the RSPB reserve of Insh Marshes, the largest expanse of flood-plain in northern Britain, Loch Garten also RSPB, the pine woods of Glenmore, Mar Lodge (NTS), Morrone Birkwood (NNR) and of course the high tops of the mountains themselves, with the corrie of Caenlochan the best place for arctic-alpine plants. For each site the most important plants, birds, mammals and insects are mentioned as well as a description of the physical nature of the site. I realise that many good wildlife sites have been missed out – but this book is covering the whole of Britain, and the prospective traveller will get a flavour of what is on offer and will be able to get more information from the list of organisations associated with the conservation and the environment at the back of the book.
The colour photographs are excellent whether conveying the atmosphere of a reed-fringed loch or the details of a Greater Butterfly Orchid, and the line drawings are finely executed. **Edna Stewart**

ARABLE PLANTS – A FIELD GUIDE
Phil Wilson and Miles King

English Nature and wildguides, Hove, Sussex, 2003, 312 pages. Hardback, colour illustrations, photographs, keys and diagrams. ISBN 1 903657 02 4 £15

The title puzzled me to the extent that I went to the dictionary to find the meaning of "arable". It is from the Latin to plough and means land capable of being ploughed; fit for tillage as opposed to pasture or woodland. Perhaps I am being pedantic but I would expect the book to be about crops rather than, as this is, about the plants that live with the crops. On page 50 the scope of the book is identified as "rare plants found on arable land…" and contains advice to farmers as to how to manage their land for these plants, rather than how to get rid of them as weeds.
There is an interesting section on the history of arable farming and another on the biology of those plants which can live with crops. They are mainly ephemerals and capable of completing their life cycle within the timing of traditional arable farming. Most are annuals but a few perennials, and both of these groups can survive because of their deep roots.
The main part of the book is an account of each species. This contains a lot of useful information, good clear photographs, black and white illustrations of important points for identification and distribution maps. The maps include Scotland and Northern Ireland although the book states that it is only concerned with the situation in England but probably most of the information could apply here as well. **Jean M Millar**

KEYS TO THE FRESHWATER MICROTURBELLARIANS OF BRITAIN AND IRELAND WITH NOTES ON THEIR ECOLOGY
J O Young

Freshwater Biological Association Publication No. 59, Ambleside, UK, 2001, 142 pp, softback, line drawings. ISBN 0 900386 66 5 £16

Many observant field naturalists will have turned over stones at the margins of streams and lakes and found planarians, often referred to as flat worms. They are the macroturbellaria whereas this publication deals with their generally smaller cousins – the microturbularia. The word 'worm' covers a multitude of organisms just as 'bug' can embrace anything from the bacteria responsible for the common cold to greenfly that eat our lettuces. Basically the microturbellarian worms are very small usually free-living aquatic flatworms and belong to the phylum Platyhelminthes. Familiar members of this phylum are tapeworms and liver flukes although most people do not have personal experience.
One of the nearest relatives to those discussed in this booklet is the New Zealand flatworm. Its notoriety precedes any actual contact. How many Glaswegians that have heard of this creature would actually recognise it face to face? It is certain that microturbellarians would generate even fewer recognition signals. Notwithstanding the relatively obscure nature of the microturbellarians, as usual the FBA has through its author produced a definitive account of the subjects under scrutiny. Even though there are many statements in the text bemoaning the lack of knowledge of basic aspects of their biology this publication contains a surprising amount of detail. That these data originate from continental Europe or North America may be a little surprising. One is often told that British natural history is the best understood in the world because of the density of interested people and a long tradition of study. Are

we so shy of microscopes that a group such as the microturbellarians, with more species in Britain than there are orchids, butterflies, ducks or geese, is virtually unknown?

For those who enjoy a challenge here is a subjeet for study in which almost every observation will be new. For others an armchair perusal of the contents of this publication will highlight most forcibly how little we know of the life forms with which we share this planet. Concerning the microturbellarians this applies to our country as well as the rest of the world. This reviewer searched in vain for any significant references to Scotland so indeed it would be new territory. **EG Hancock**

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 159-164.

BLODWEN LLOYD BINNS BEQUEST PROJECT REPORTS

Rural Community Agriculture in Chitral, Hindu Kush.

GLASGOW AND THE HINDU KUSH

Azra Meadows and Peter Meadows, University of Glasgow

A recent multidisciplinary conference on 'Sustainability of Communities in Remote Environments: Hindu Kush, Pakistan' in September 2004 brought together international experts and local mountain people to highlight problems faced by remote communities in mountain environments. It was partly funded by the Blodwen Lloyd Binns Trust of the Glasgow Natural History Society.

The three-day international conference was held at the summer campus of Peshawar University in the Himalayan foothills of Pakistan at 7600 feet, and received considerable national media coverage. It was organised by Azra Meadows, Peter Meadows and Raymond Stoddart all of the Institute of Biomedical and Life Sciences, University of Glasgow, Professor Ihsan Ali, Director of Archaeology and Museums, North West Frontier Province, and Nadeem Akbar, Director of the American Institute of Pakistan Studies, Islamabad. The above institutions and the Glasgow Natural History Society sponsored the conference.

Delegates from Denmark, Italy, Pakistan, the UK and USA, together with local schoolteachers, focussed on the sustainability of remote communities including the importance of health and education. They also considered the sustainability of plant and animal communities, of biodiversity, and of the geological and archaeological record, including the role of rivers and natural hazards in landscape modification. This included results of the 1999 Royal Geographical Society International Hindu Kush Expedition to Chitral led by Peter Meadows, Azra Meadows of the University of Glasgow and Professor Israr-ud-Din of the University of Peshawar. This expedition was also partly funded by the Blodwen Lloyd Binns Trust of the Glasgow Natural History Society and the Linnean Society of London.

Glasgow Natural History Society and Glasgow University have benefited greatly from the expedition and the conference. Participants in both activities showed a great interest in the Glasgow Natural History Society. There may even be new members as a result. We have also had many inquiries regarding undergraduate, postgraduate and postdoctoral programmes at the university. In this context one of our former graduates from the 1960's, Mr Kenny Macrae, now a senior staff member at Herlufsholm Skole (the Eton of Denmark) gave a thought-provoking analysis of local educational needs at the conference. Together with Raymond Stoddart – a member of the Glasgow Natural History Society, Kenny Macrae has played a central role in attracting students from Denmark to study at Glasgow University. It is hoped to extend this initiative and to develop a tripartite arrangement between Glasgow University, Denmark and Pakistan.

CONFERENCE PROGRAMME

'SUSTAINABILITY OF COMMUNITIES IN REMOTE ENVIRONMENTS: HINDU KUSH, PAKISTAN'

Department of Archaeology and Museums NWFP Pakistan, Glasgow Natural History Society, University of Glasgow

Baragali Summer Camp, University of Peshawar. 6th to 8th September 2004.

MONDAY 6TH SEPTEMBER 2004

Inaugural Session 10.30 to 12.45 hrs

Chief Guest: Mr Ejaz Ahmad Qureshi, Chief Secretary, Government of NWFP.
Host: Mr Amjad Nazir, Secretary Culture, Sports, Tourism, Archaeology, Youth Affairs, Government of NWFP.

10.30	Guests to be seated.
10.40	Arrival of the Chief Guest.
10.45	Recitation from the Holy Quran.
10.50 to 11.00	Mr Amjad Nazir, Secretary Archaeology, Government of NWFP. Welcome Address.
11.00 to 11.15	Peter Meadows, University of Glasgow, UK. Introduction to the Conference.
11.15 to 11.40	Ihsan Ali, Director Archaeology and Museums, Government of NWFP. Archaeological Heritage of NWFP and Future Prospects.
11.40 to 12.00	Brian Hemphill, California State University, USA. Bioanthropology of the Hindu Kush borderlands: A dental morphology.
12.00 to 12.20	Nasser Ali Khan, Director, Institute of Management Sciences, Peshawar. Globalisation of mountain regions: evolving policy initiatives.
12.20 to 12.30	Address by the Chief Guest Mr Ejaz Ahmad Qureshi, Chief Secretary, NWFP.
12.30 to 12.45	Vote of Thanks by Director Archaeology, NWFP.
12.45 to 14.00	Lunch and Prayers.

Afternoon Session I 14.00 to 15.30 hrs

Chairperson. Professor Brian Hemphill Co-Chairperson. Dr Anna Filigenzi

14.00 to 14.20	Luca Colliva, Italian Archaeological Mission in Pakistan. The Aspidal Temple of Taxila: Old interpretations and new evidences.
14.20 to 14.40	Professor Israr ud Din. University of Peshawar. Population growth, settlement and pressure on forests in Chitral.
14.40 to 15.00	Adam Nayyar, Lok Virsa, Islamabad. Spatial and temporal perceptions among the Shina speakers of Pakistan.
15.00 to 15.20	Kenny Macrae, Herlufsholm Skole, Denmark. Some thoughts on education in the Hindu Kush.
15.20 to 15.30	Question / Answer session.

Afternoon Session II. 15.30 to 17.00 hrs.

Chairperson. Dr Nasser Ali Khan Co-Chairperson. Mr Kenny Macrae

15.30 to 15.50	Syed Ayaz Ali Shah. Directorate of Archaeology and Museums, NWFP. Darag dialect: a Kalkot Kohistani and its relations with the dialects of the neighbouring valleys.
15.50 to 16.10	Muzzafar Hussain. Starslands Grammar School, Booni, Chitral. Women's status in Chitral.
.16.10 to 16.30	Anna Filigenzi, IsIAO, Rome, Italy. New archaeological researches in Swat Valley.
16.30 to 16.50	Randall Law*, University of Wisconsin, USA. Harappan contexts with NWFP and Jammu and Kashmir: new evidence.
16.50 to 17.00	Question / Answer session
17.00	Tea/Refreshment

TUESDAY 7TH SEPTEMBER 2004

Morning Session I. 09.00 to 10.30 hrs.

Chairperson. Dr Ruth Young Co-chairperson. Dr Adam Nayyar

09.00 to 09.20	Raymond Stoddart, University of Glasgow, UK. Soil transmitted helminths in the Hindu Kush, and their significance in the health of primary school children.
09.20 to 09.40	Muhammad Zahir. Government College, Peshawar. Excavations at Parwak, Chitral.
09.40 to 10.00	Razia Sultana. Quaid-e-Azam University Islamabad. Pushtoons migration and settlement in the Peshawar Valley under the shadow of the Hindu Kush.
10.00 to 10.20	Saifullah Jan, Rumbur Valley, Chitral. Kalasha Culture.

10.20 to 10.30 Question / Answer session

Tea Break 10.30 to 11.00 hrs.

Morning Session II. 11.00 to 12.30 hrs.

Chairperson. Dr Syed R. Baqri Co-chairperson. Mr Raymond Stoddart

11.00 to 11.20 S. Sajidin Hussain, M. Sheikh, M. Mudasser, and M. Nadeem.
Global Climate Impact Studies Centre, Islamabad.
Climate change variability in mountain areas of the Hindu Kush and its implication for water and agriculture resources.

11.20 to 11.40 Ruth Young, University of Leicester, UK.
Archaeological discoveries in the Chitral Valley.

11.40 to 12.00 Syed Harir Shah, Focus Humanitarian Assistance, Chitral, Pakistan.
Community based disaster and risk management (CBDRM).

12.00 to 12.20 Luca Olivieri*, IsIAO, Rome, Italy.
Preliminary results of the 2004 survey campaign in the Kandak Valley and adjacent areas.

12.20 to 12.30 Question / Answer session

Lunch and Prayers. 12.45 to 14.00 hrs.

Afternoon Session I. 14.00 to 15.30 hrs.

Chairperson. Syed Harir Shah. Co-chairperson. Mr Luca Colliva

14.00 to 14.20 Peter Meadows, University of Glasgow, UK.
Mountain climates, weather and the historical record.

14.20 to 14.40 Aziz Ahmed, Mastuj Model School, Mastuj, Chitral.
Education in a Chitrali context.

14.40 to 15.00 Lutf-ur-Rehman, Government College, Charsadda, NWFP.
Excavations at the stone-age site at Angu Gatkai, Bajaur, Pakistan.

15.00 to 15.20 David Archer*, JBA Consulting Engineers and Scientists, UK.
Climate, climate change and hydrology of the Upper Indus Basin.

15.20 to 15.30 Question / Answer session

Afternoon Session II. 15.40 to 17.00 hrs.

Chairperson. Professor Israr ud Din. Co-chairperson. Dr Azra Meadows

15.40 to 16.00 Asghari Bano, Quaid-e-Azam University, Islamabad.
Community development in Skardu and Hunza.

16.00 to 16.20 Adil Zareef, Sarhad Conservation Network, Peshawar, NWFP.
Role of civil society in protection and preservation natural and cultural heritage.

16.20 to 16.30 Question / Answer session

16.30 to 17.00 Birgitte Sperber*. Ribe, Denmark.
Video Film. Water in the Hindu Kush – nature and culture interplay.

WEDNESDAY 8TH SEPTEMBER 2004

Morning Session I. 09.00 to 10.20 hrs.

Chairperson. Mr Nadeem Akbar Co-chairperson. Dr Asghari Bano.

Chief Guest, Mr Andrew Picken, Deputy Director, British Council, Pakistan.

09.00 to 09.20 Syed R. Baqri, Pakistan Science Foundation, Islamabad.
Sources of gypsum in the Indus Valley as utililised by the Harappan Civilisation.

09.20 to 09.40 Amir Nawaz Khan, Jamil Ahmad & Atta ur Rehman, University of Peshawar.
Causes and impacts of flash floods in the Hindu Kush region: a case study along the Chitral Buni road.

09.40 to 10.00 Azra Meadows, University of Glasgow, UK.
Remote communities and their balance with the environment

10.00 to 10.20 Question / Answer session

Tea Break 10.20 to 10.40 hrs.

Morning Session II. 10.40 to 11.40 hrs.

Chairperson. Professor Dr Ihsan Ali

10.40 to 11.40 Resolutions and Recommendations.
Vote of Thanks to delegates.

Lunch and Prayers. 12.00 to 13.00 hrs.

13.00 onwards. Afternoon Excursion to Galiyat high mountain valleys in the foothills of the Himalayas.

THURSDAY 9th SEPTEMBER - 09.00 Delegates Depart.

* = paper presented by another speaker.

BREEDING PROCELLARIIFORMS IN THE AZORES ARCHIPELAGO: ABUNDANCE AND DISTRIBUTION ACCORDING TO PREDATORS PRESENCE

Ana de León Marti

Ornithology Unit, Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, UK

Email: adele001@udcf.gla.ac.uk

In 2003 a Glasgow University Exploration Society expedition visited the Azores archipelago, with the primary objective of carrying out a variety of studies of Azores seabirds.

One aspect of this work was to collect data on the influence of the presence of introduced predators on the distribution and abundance of procellariiforms breeding on islands and islets of this archipelago. A considerable number of non-native animals have been introduced to the Azores during the last centuries (Mathias *et al.* 1998). Petrels and small shearwaters are particularly vulnerable to attack by land mammals introduced from mainland ecosystems. Their burrows, that may provide protection from gulls, give little protection from rats or mustelids, small enough to enter the tunnels. The birds mostly have evolved no effective direct protection from such attack apart from oil spitting. The presence of introduced predators on some islands might have been the reason of local extinctions, and probably limits opportunities for the establishment and growth of breeding populations of these burrow-nesting seabirds. In fact, most colonies are now confined to precipitous cliffs and islets, which may be a result of predation threats by introduced mammals (Monteiro *et al.* 1999).

The expedition took place during August 2003, and fieldwork was directed to get all the information not available in the bibliography about procellariiforms and predators' distribution and abundance. The study includes the nine main islands in the Azores archipelago, and most of the accessible islets with a minimum size to enable seabirds breeding on it. Habitat and topographical factors seem to affect predation both through their influence on the distribution of predators (e.g. inaccessibility of the islands and distance to the coast) and also through that on seabirds (e.g. breeding site availability). So, we also had to consider other variables such as the area and altitude of the island, the geology (rock substrate, presence of cliffs, boulders...), the presence of humans living on the islands (or when was it last inhabited), frequency of human visits to the islets, presence of illumination, distance to next inhabited island.

The species of study are Madeiran storm-petrel *Oceanodroma castro,* Bulwer's petrel *Bulweria bulwerii,* the abundant cagarro (Cory's Shearwater) *Calonectris diomedea,* Manx Shearwater *Puffinus puffinus,* Little Shearwater *Puffinus assimilis baroli;* their avian predators: Yellow-legged gull *Larus cachinnans atlantis* and Buzzard *Buteo buteo;* and the introduced mammals and possible predators: Cat *Felis catus,* Norway rat *Rattus norwergicus,* Black rat *Rattus rattus,* House mouse *Mus domesticus,* Hedgehog *Erinaceus europaeus,* Weasel *Mustela nivalis and* Ferret *Mustela furo.*

Presence or absence of each species on the islands has been studied mainly by bibliographic search and interviews with local naturalists, researchers or natural wardens. This information was complemented with direct sight, collection of excrements, and the employment of rat sticks. This technique has been shown to be effective in estimating relative rat abundance (Zonfrillo and Monaghan 1995). It consists of pieces of wood (15 x 2 cm, e.g. tong depressors) which are soaked in liquid margarine or butter, and placed along transects on the islets. Presence of rats is easily detected because they conspicuously chew the sticks.

Overall we obtained information on the distribution of procellariiforms and predators on 28 islands and islets. Cats, ferrets, weasels and hedgehogs are only found on the 9 main islands. Nevertheless, rats are able to swim and to survive on islets, so they are the main threat on islets. Of the 19 islets studied we visited 14, and we put rat sticks in all of them, prospecting simultaneously the presence of breeding procellariiforms. We found clear evidence of the presence of rats in 3 of these islets (Ilhéus de S. Lourenço, da Mina and Vila Franca). Additionally another 2 islets could suffer from sporadic visits of rats and other predators during the low tide (Ilhéus de S. Anténio and Rosto do Cão), or even cats, which were seen wandering in the last one.

Our preliminary results suggest that in Azores, the only procellariiform that seems to be able to coexist with rats is the Cory's shearwater (*Calonectris diomedea*). Nevertheless, the Madeiran storm petrel (*Oceanodroma castro*) only breeds in significant numbers in 3 islets (Vila, Praia and Baixo), being absent of most of the islets, even when these islets are completely clean of predators. This suggests that, apart of the presence of predators, other important ecological constrains must exist and limit the abundance and distribution of storm petrels in Azores.

Acknowledgments

We would like to thank Helder Fraga (Faial), Pedro Domingues (Corvo), Paulo Faria (Flores) Juan Simón, Maria Carvalho, Joel Bried (University of the Azores), Márcia Santos and Henrique Simoes (Santa Maria) for their help during the fieldwork and all the information they provided. We would also like to thank various sources of funding of Azores 2003, namely: Carnegie Trust, Glasgow Natural History Society, Glasgow University Court, Portuguese Foundation for Science and Technology, Royal Geographical Society and the Seabird Group.

References
Mathias, M.L., Ramalhinho, M.G., Santos-Reis, M., Petrucci-Fonseca, F., Libois, R., Fons, R., Ferraz de Carvalho, G., Oom, M.M., and Collares-Pereira, M. 1998. Mammals from the Azores islands (Portugal): an updated overview. *Mammalia* 62 (3):397-407.
Monteiro, L. R., Ramos, J. A., Pereira, J. C., Monteiro, P. R., Feio, R. S., Thompson, D. R., Bearhop, S., Furness, R. W., Laranjo, M., Hilton, G., Neves, V. C., Groz, M. P., & Thompson, K. R. 1999. Status and distribution of Fea's Petrel, Bulwer's Petrel, Manx Shearwater, Little Shearwater and Band-Rumped Storm petrel in the Azores Archipelago. *Waterbirds* 22(3): 358-366.
Zonfrillo, B. and Monaghan, P. 1995. Rat eradication on Ailsa Craig. 5th International Seabird Group Conference, Glasgow.

PREDATION ON TERN EGGS BY EUROPEAN STARLINGS IN THE AZORES

Verónica Neves
Ornithology Unit, Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ, UK
IMAR-Açores, Cais de Santa Cruz, 9901-862 Horta, Portugal
Email 0011610n@student.gla.ac.uk

The aim of this study was to collect data on predators of the roseate tern population of the Azores, as this is now one of the largest populations of roseate terns remaining in Europe.

During the last few years, the mixed common and roseate tern colony at Vila islet (Santa Maria island, Azores archipelago) has been suffering from increasing rates of egg predation. Depredated eggs were noted in the islet since annual monitoring was initiated in 1989, when Adrian del Nevo counted 154 roseate tern nests and found "several eggs predated" (IMAR-Açores unpublished data). In 1999, 167 nests of roseate tern and 181 nests of common tern *Sterna hirundo* were counted at Vila islet and 112 eggs (of both species) were found depredated (Neves, pers. obs.). Hays *et al.* (2002) report pecked and partially eaten eggs on Vila islet in 1999 and 2000. These two studies mention the fact that a pair of Eurasian buzzards (*Buteo buteo rothschildi*) was also nesting on the islet and have regularly taken large chicks and adult terns, but it is not suggested that the buzzard ate the eggs. On another colony in the Azores, Ramos & del Nevo (1995) observed a grey heron *Ardea cinerea* preying on eggs and chicks of roseate tern.

Ramos & del Nevo (1995) concluded that in the early 1990s the role of predation on tern colonies was insignificant as a factor influencing nest-site selection by terns in the Azores. The high rates of egg predation observed at Vila islet in the recent years are presumed to have very serious adverse effects on the Azores population, since Vila islet is one of the most important tern colonies in the archipelago. Vila islet has been declared an Important Bird Area (IBA 014) and holds a mixed colony of common and roseate terns that also include the only known breeding pair of sooty terns (*S. fuscata*) in Europe (Monteiro 2000). Vila Islet has no mammalian predators and holds about 20% of the Azores roseate tern population (201 pairs in 2002 when the total breeding population was 991). Egg laying in the Azores occurs between late April and late July (Hays *et al.*, 2002; Ramos & del Nevo, 1995), prior to which terns concentrate in clubs and gradually start displaying, courting, and nesting behaviour.

During this study only starlings were observed eating tern eggs. However gulls and turnstones (*Arenaria interpres*) were also observed in the islet and could have been undetected as predators. In 2002 there were 201 Roseate Tern nests at Vila Islet and 46% were depredated. Eleven complete sequences of egg predation by starlings were observed and several more incidents indicated predation. Observations from predation sequences showed that predation usually occurred by actions of more than one starling. A small group of starlings (up to 6 individuals) would approach the area of a nest even when a bird was incubating. The incubating bird would fly up to mob one of the starlings, at which point the other individuals moved quickly towards the nest and broke the eggs. On many occasions starlings were also seen returning to the exact places where predation had occurred, and sometimes even removing egg remains from the nest and taking them away from the nest to eat them, while in other cases unsuccessful predation attempts were observed. However, starlings seemed quite persistent even when they were mobbed, usually returning to exactly the same place they were feeding in a number of seconds. Starlings tend to roost up to 200 m above sea level (Feare 1985); in the Azores they roost abundantly on remote sea cliffs and on islets (pers. obs.) and the roosting areas largely overlap with tern breeding areas. However starling predation of tern eggs has not been detected at other colonies in the Azores. Caloura islet off São Miguel is a good example. The number of Common and Roseate terns breeding in this islet has increased over the last years. A few hundreds of starlings roost in the islet and adjacent coast (according to local people the numbers are increasing). However no depredated eggs were found during several visits to the islet. As opposed to Vila islet, breeding of European starlings at Caloura islet has never been confirmed. This fact together with the fact that Caloura is much more rocky and has little vegetation may contribute to the absence of resident starlings.

Starlings are not the only threat to terns in the Azores. Observations conducted during this study

suggest that tern colonies in the Azores may not be sufficiently protected from human disturbance. Fishermen were seen landing on Mós islet, Terceira Island to harvest rock pigeons and they caused considerable disturbance in the tern colony. The main roseate tern colonies in the Azores, which are protected by European Union and Portuguese conservation legislation, should be clearly identified with notice boards to warn people to avoid entering tern colonies during the breeding season.

Predator control has long been considered necessary for the survival of the north eastern American population of roseate terns (Nisbet 1981) and many studies have reported on management strategies in tern colonies and the results of their implementation. In the Azores, some form of controlling the impact of starlings on roseate tern seems necessary if the Azores population of roseate terns is to be maintained.

ACKNOWLEDGEMENTS

I am very grateful to José Maria Soares for skilful and safe transport to the islet and to Raúl Sousa and João Batista for logistic support. I would also like to thank the Portuguese Foundation for Science and Technology and the Glasgow Natural History Society for funding. This study was undertaken with a permit from the Direcção de Serviços de Conservação da Natureza / Secretaria do Ambiente / Açores"(1/CN/2002). I would also like to thank the Department of Oceanography and Fisheries (University of the Azores) for their collaboration.

REFERENCES

Feare C., 1984. The starling. Oxford University Press, New York.

Hays H., Neves V., Lima P., 2002. Banded Roseate Terns from different continents trapped in the Azores. Journal of Field Ornithology 73, 180-184.

Monteiro L. R., 2000. The Azores. In Heath M.F. & Evans M.I., eds. Important Bird Areas in Europe. 463-471.

Nisbet, I. C. T. 1981 Biological characteristics of the Roseate Tern, Unpublished report USFWS.

Ramos J.A. & del Nevo A.J., 1995. Nest-site selection by Roseate Terns and Common Terns in the Azores. Auk 112, 580-589.

Glasgow Naturalist 2004. Volume 24. Part 2. Pages 165-168.

OBITUARIES

Alan Muirhead Maclaurin. (1907-2003)

Alan and Sheila Maclaurin

Alan Maclaurin died on 17th February 2003 after a prolonged but fortunately painless illness. He joined the Glasgow Natural History Society (or the Andersonian Naturalists of Glasgow as it then was) in 1944) and at the time of his death was the longest serving member of the society.

Living in Kilmacolm, the proprietor of a tannery at Bridge of Weir, he retired in 1974 and moved to Dollar in 1980. After a while, due to his affliction, he was no longer able to take an active part in the study of Natural History. Though probably unknown to many present members of the Society, he is well remembered by the older ones as he had in his time made a significant contribution by attending, speaking and exhibiting at meetings, by arranging and participating in excursions, and by publishing the Glasgow Naturalist. His wife, Sheila, who predeceased him by several years, was a family member who participated in many of his activities.

Mainly interested in Lepidoptera, he produced short notes on the Pearl-bordered Fritillary (1966), the Yellow-tailed Moth (1967), the Death's Head Hawk Moth, the Transparent Burnet Moth (1971) and the Bedstraw Hawk Moth (1973), as well as detailed lists of the Lepidoptera of Flanders Moss (1974) and of the moths of Rowardennan (1976). A more general work was his undated report entitled "The insects found in the Clyde-Muirshield Regional Park" which after a general account listed several species of Odonata, Hymenoptera and Coleoptera as well as Lepidoptera.

He served on Council from 1950-1951, was Vice President from 1961 to 1963, and was a member of the Zoology Section Committee from 1985 to 1987. In 2000 he was elected to honorary membership of the society.

His collection of Lepidoptera, mainly from the Kilmacolm area, included 25 species of butterflies and 279 species of moths (represented by some 2400 fully labelled specimens in all) and was donated to Paisley Museum and Art Gallery in 1980. It has since been incorporated into the main collection there.

In addition to his scientific work, Alan will be remembered as a robust and cheerful person whose enthusiasm and energy were inspirations to all. It is on record that towards the end of his active years, when other participants were concerned that he had been left behind, he had actually gone ahead and was well in front of the others.

He will be sorely missed and our condolences are extended to his relatives and numerous friends.

I am grateful to Betty Crowson, Richard Weddell, Ian McCallum, Geoff Hancock, Richard Sutcliffe, the staff of the Paisley Museum and Mrs Florence Milne (nee Maclaurin) for help in composing this note.

Ronald M. Dobson.

Agnes Marjorie Allan Craib, 1912-2003
President 1982-1984

Agnes Craib was Nancy to everyone. The daughter of Robert and Ellen Gilmour, Nancy was born in Meikila, Burma whilst her father was a serving officer in the British Army. On her return to Scotland, she was educated at Coatbridge Secondary School, where she was girl's dux in year 1929 –30. She then went on to the University of Glasgow and in 1935 graduated M.A. (honours in modern languages) with particular distinction in French. Her studies required sojourns in both Germany and France and this led to a life long friendship with the Petre family (Louis and Lille), who lived near Marseilles; she cherished that relationship and continued to visit the Petres for many years. In August 1942 she married Captain Arthur Craib of the Merchant Navy at Bargeddie Parish Church in Ballieston, near her family home. Sadly, Arthur died of peritonitis while at sea in 1943 and Nancy did not marry again. She had already suffered a tragedy when she lost her brother Johnny, a navigating officer in the Merchant Navy, to enemy action in the Atlantic in 1942.

She taught modern languages first at Albert Senior Secondary, then Whitehill S.S. before becoming head of department at Shawlands S.S. in 1968, and she retired in 1972. In the words of Bob Livingstone, her fellow teacher and friend of many decades, "Nancy was not only an outstanding teacher devoted to her work, she played the violin in the school orchestra and was a key figure in the drama department." A comment made to her by one Head Teacher was "I asked for a big strong man and they sent me a wee woman" but he quickly realised that he had underestimated her abilities. Though not reaching 5 feet tall, Nancy had no problem with discipline in class.

Nancy lived in Highburgh Road from 1965 to 1999, when she moved to the shelter of St John Court. With her health failing, she moved to Ballymena, Northern Ireland in 2002, to stay with her niece Mary Stewart, where she died peacefully on 22nd August 2003. She was cremated at Roselawn Crematorium, Belfast, with her nephews and niece present in a private ceremony, at her own request.

Having served in various capacities culminating in the Presidency, Nancy was a much-loved member of the Society. She was a great asset because of her sociability and immediate friendliness to new members. She was a keen natural historian with a great interest in both birds and plants. Finally, I can do no better than quote the completely apt words of Bob Livingstone, "Nancy loved her work, she loved people and she loved nature".

J.H.Dickson

Irene Nove, 1918 –2004

"Definitely Helleborine"
Dick Hunter and Irene Nove
Stepps, 9 Sept 1985
By Jean Millar

Irene Nove was born on 11th November 1918 in West Calder, Midlothian. As this was Armistice Day when World War I ended, her parents named her after the Greek goddess of peace. Her mother even claimed that she was born at 11a.m, the exact moment the Armistice Treaty was being signed.

Irene was educated in Hillhead High School and went on to Glasgow University where she earned an M.A. (Hons.) in French and German. As part of the requirements for this, she spent a year in Besancon. France, teaching in a girls' school, where she recalled with delight the lovely bread and chocolate they served with morning break. She loved France and was to go there frequently throughout her life, and was staying in France with one of her many friends when war broke out so had to leave rather smartly. She had a true gift for languages, winning prizes for her Latin prose at school and eventually becoming fluent in French, German and Russian.

Irene's lifelong passion for words could illuminate situations in completely unexpected ways, as on the occasion that she was introduced a young biologist and politely enquired what he was working with. "Caecilians" he replied. Most people would have reacted by moving to a safer topic, like the weather, but not Irene; after some thought she suggested that the creatures might be blind. St. Caecilia was the blind patroness of music, and while Caecilians aren't musical, they are nearly sightless.

During World War II, she moved to London and then was invited to work at Bletchley Park decoding centre, using her German skills. She was very reticent about her time there because the Official Secrets Act prevented her from speaking about it. Once a few books started to come out, after documents were declassified, she became a little more forthcoming, but only a little! It was partly the effect of having had such extreme secrecy

drilled into her at the time, and partly a modest desire not to be seen as making a song and dance of what she viewed as only a very minor contribution. This was a very typical part of Irene's personality.

She met her husband Alec when they were both working at the Board of Trade in London. Story goes that she was intrigued by the persistent crunching noises from a nearby office, which turned out to be Alec shelling nuts beneath the heel of his shoe. Meantime, he was wondering who the girl in the department was who wrote her number 7s the French way. They married in 1949 and she took over the raising of Alec's two young sons, David and Perry. They moved to Glasgow in the mid-50s, where she looked after the children while Alec's expertise in Russian economics took him travelling throughout Eastern Europe. The family was later complete with the birth of Charles. In 1963, Alec was appointed Professor of Economics at the University. Alec's academic standing led to lecture engagements all over the world, and Irene was delighted to accompany him whenever a suitable opportunity arose. Thus she forged lasting friendships with kindred spirits in many foreign countries. She had a wonderful capacity for friendship.

Irene's love of the outdoors led to a love of botany and one of her favourite places in all the world was the Isle of Coll with its beautiful beaches and flowers. I was fortunate to join her and Alec there one summer where we had a fine time botanising. Irene enjoyed enormously the story of one botany outing on a piece of waste ground somewhere in Glasgow, where everyone was peering at the ground, rather to the bemusement of two local lads, who started helpfully contributing findings of their own, such as: "Haw look, err a thistle, err a deid moose".

She laughed with family and friends, at that story many times. Indeed the small illustration by Jean Millar showing her with Dick Hunter is typical of many happy days botanising. Irene, Jean Millar, Mike Jarvis and I spent many days researching Kenmuir Wood on the banks of the Clyde, once a great beauty spot, where herbalists came to collect flowers. They left a record of their findings and this gave us incentive to re-explore. Irene greatly enjoyed her botanising excursions but the stroke she suffered in the 1980s made it too difficult for her to do the amount of necessary walking so she reluctantly had to leave our group. Another great pleasure she had to give up was cycling which was a great deprivation.

Her abiding passion, however, was music and she studied harpsichord with Jannetta Gould until a few years before she died. Indeed over one winter, Morton Gould recorded Irene playing all the Goldberg variations - quite an achievement. Music was another enthusiasm I shared with Irene and we became members of the Glasgow Harpsichord Society at the same time. We loved to play duets on the harpsichord. She had a record of two Russian boys playing one of Mozart's harpsichord sonatas very brilliantly so we decided to play this together for the Glasgow Harpsichord Society Concert, in our own way. She had her own harpsichord, specially commissioned from Goble of Oxford. The soundboard was decorated with flowers from Coll, painted from pictures she sent to the makers. She wanted the harpsichord to go to a good home, where it would be put to regular use and would benefit young people learning the instrument, so her son Charles arranged to give it to the Music Department at the University.

For her 80th birthday, Irene came up with a truly appropriate idea. Her celebration was also a contribution to the arts. She rented a small concert venue and commissioned the Lesley MacLeod early music ensemble to perform. It was a memorable evening.

Although music was Irene's chief delight, she had a multiplicity of interests. She was never happier than when enjoying Glasgow's West End - particularly the Botanic Gardens - on sunny days and bemoaned the fact that there weren't nearly enough of them. She was a voracious reader, a prize-winning crossword solver a, theatre-lover, and an unbeatable Scrabble player. She was always ready for a good blether over a cup of tea. She loved, and was much loved by, her large extended family, which included grandchildren and great-grandchildren. To Irene, of course, the family was never complete without at least one cat. There was a long procession of them, all dear to her heart.

All who knew her will recall she had a ready wit, and a pithy response poised to debunk pompous officialdom. She was a wonderful lady, cherished by all her many friends.

Agnes Walker

Proceedings 2002

The Chairman, place, number attending, lecturer's name and title of lecture are given for most meetings.
GKB - Graham Kerr Building; WILT Western Infirmary Lecture Theatre

15th January
Bob Gray, GKB,36, Paisley International Colour Slide Exhibition. Compiled by members of Paisley Photographic Club, presented by Winifred Brown and projected by Jim Campbell.

12th February
Bob Gray , GKB, 32,"Geology – Earth Processes & the Stability of Life", Dr Jim McDonald.

26th February
Bob Gray , GKB,30, 72rd AGM. Reports were given about activities during 2001 and elections were held. . There were 3 council meetings and 4 BLB meetings held during the previous year.
The AGM was followed by Bob Gray giving a Presidential Address..

March 12th
Roger Downie , GKB, 38,"Behaviour & Aggression in Sticklebacks and Salmon", by Prof. F.A. Huntingford..

April 9th
Roger Downie, GKB, 27,Members Slide Night.

May 14th
Roger Downie, GKB, 29,"Bursting with Biodiversity – An Action Plan for Glasgow " by Keith Watson.

June 11th
Summer Social to Balmaha.

Excursions
24 excursions took place throughout the year.

11th September
Roger Downie, GKB, Joint meeting with Scottish Pakistani Association "Exploration in the Karakorum and the Hindu Kush" Speaker Dr Mike Searle.

20th September
Roger Downie, GKB welcomed members to the Exhibition Meeting with Wine & Cheese.

8th October
Roger Downie, GKB,41,"The Natural History of the Falklands, South Georgia and the Antarctic Peninsula" by Prof. John Knowler.

16th October
Roger Downie, WILT. .DEEB/GNHS BLB Lecture given by Dr Jeff Parker. "Golden Flies – Sunlit Meadows. A tribute to the Yellow Dung Fly." .

12th November
Roger Downie, GKB,48, "A Tale of Two Butterflfies" speaker Mr John Mitchell

10th December
Glasgow University Club. Christmas Dinner. 41,
The meal was followed by Dr John Fletcher Stewart talking about Red Deer..

Officers and Council
Session LXXII 2002.

President:
Roger Downie, BSc. PhD.

Vice Presidents:

.
Ruth Dobson, BSc, MSc.
Richard Weddle, BSc.
Ian McCallum, CEng., MICE, FIHT

Councillors:
Prof. Jim H. Dickson, BSc, PhD. FLS, FRSE.
David Palmar. MA, Dip Ed, Dip.Comp.Ed., PGCE.
Russell Semple, BSc.
Robin Jones, BSc, PhD
Edna Stewart, BSc.
Robert Gray, BSc, MIBiol

General Secretary:
Kirsty A Kennedy-Wylie BSc, MSc.

Assistant Secretaries.
Fiona Giffard, BSc. (Meeting Minutes)
Edna Stewart, BSc. (Minute Book)
John Lyth, BSc. (Publicity)
Hazel Rodway (Social)

Treasurer:
Morag Mackinnon, BA, BSc

Membership Secretary:
Richard Weddle, BSc .

Librarian: Joan Chapman
Assistant: Catherine Aird, MA, AL.(Library)

Editors:
Azra Meadows, BSc, MSc, PhD, CBiol, MIBiol, .FLS
Peter Meadows, MA, BA, CBiol, .FIBiol., FLS, FRGS, SQA.

Newsletter Editor:
Prof. Norman R. Grist, BSc, MBChB, FRCP , FRCPath.

Section Convenors
Keith Watson, BSc, MSc. (Botany)
Richard Weddle, BSc. (Bio-Recording)
Joyce Alexander (Excursions)
Julian Jocelyn (Geology)
Sandy McNeil (Ornithology & Photography)
Geoff Hancock, BSc, FMA. (Zoology)
Robin Jones (Winter Programme)

BLB Scientific Advisor
Peter Macpherson FRCP, FRCR, DTDC, FLS.

Proceedings 2003

The Chairman, place, number of members attending, lecturer's name and title of lecture are given for most meetings.
GKB - Graham Kerr Building; WILT-Western Infirmary Lecture Theatre

14th January
Roger Downie, GKB,30, Paisley International Colour Slide Exhibition. Compiled by members of Paisley Photographic Club, presented by Winifred Brown and projected by Jim Campbell.

11th February
Roger Downie, GKB, 37,"Galapagos Finches", speaker Dr Lucas Keller.

25th February
Roger Downie, GKB, 28,73rd AGM. Reports were given about activities during 2002 and elections were held. Membership stood at 317 made up of 211 ordinary, 43 concessions, 37 family, 9 honorary and 3 school members. There were 3 council meetings and 4 BLB meetings held during the previous year.
The AGM was followed by Suzanne Livingston talking on " Leatherback Turtles and Marine Conservation in Trinidad."

March 11th
Roger Downie, GKB, 35,"Peat Bogs", speaker Dr Lisa Belyea.

April 8th
Roger Downie, GKB ,27,Members Slide Night.

May 13th
Roger Downie, GKB, 34,"Scottish Birds and Man since the Ice Age", speaker Dr Robin Hull.

June 10th
Summer Social to Balmaha.

Excursions
16 excursions took place throughout the year.

19th September
GKB, Exhibition meeting with wine and cheese.

22nd September
Hunterian Gallery, "Leedsichthys – the biggest fish?" Jeff Liston gave a lecture and demonstration of assembled fossils of this huge teleost fish.

14th October
Roger Downie, GKB, 25,"Brave New World" talk from Dr Danny Beith with photographs of his travels in North America.

22nd October
Roger Downie, WILT, Third joint DEEB/ BLB Lecture. "What is the Future of Agriculture and Farmland Birds", speaker Professor Bill Sutherland.

11th November
Roger Downie, GKB,35, "Back from the Brink. Plantlife's Work in Scotland", speaker Deborah Long

9th December
Glasgow University Club. Christmas Dinner.40, The meal was followed by slides from Dr Stewart White on "The birds of Ecuador".

Officers and Council

Session LXXIII 2003.

President:
Roger Downie, BSc, PhD.

Vice Presidents:
Robert Gray, BSc, MIBiol.
Ruth Dobson, BSc, MSc.
Richard Weddle, BSc.

Councillors:
Ian McCallum, CEng, MICE , FIHT.
Janet Palmar BSc, PhD.
Russell Semple, BSc.
Robin Jones, BSc, PhD.
Edna Stewart, BSc.
David Palmar MA, Dip Ed, Dip.Comp.Ed. ,PGCE.

General Secretary:
Mary Child

Assistant Secretaries.
Fiona Giffard, BSc. (Meeting Minutes)
Edna Stewart, BSc. (Minute Book)
John Lyth, BSc. (Publicity)
Hazel Rodway (Social)

Treasurer:
Morag Mackinnon, BA, BSc

Membership Secretary:
Richard Weddle, BSc.

Librarian: Joan Chapman
Assistant: Catherine Aird, MA, AL.(Library)

Editors:
Azra Meadows BSc, MSc, Ph.D, CBiol MIBiol, .FLS.
Peter Meadows , MA.,BA, CBiol . F.Biol., FLS, FRGS, SQA

Newsletter Editor:
Prof. Norman R. Grist, BSc, MB, ChB, FRCP, FRCPath.

Section Convenors
Keith Watson, BSc, MSc. (Botany)
Richard Weddle, BSc. (Bio-recording)
Joyce Alexander (Excursions)
Julian Jocelyn (Geology)
Sandy McNeil (Ornithology & Photography)
Geoff Hancock, BSc, FMA. (Zoology)

BLB Scientific Advisor
Peter Macpherson FRCP, FRCR, DTDC, FLS.

THE GLASGOW NATURALIST
Advice to Potential Contributors

Please note that the following advice and instructions have been changed from previous issues of the journal.

1. The Glasgow Naturalist publishes papers, short notes and book reviews. Book reviews are commissioned. Books reviewed are kept in the Society's Library. Papers and short notes must be word processed in Microsoft Word. They should be submitted electronically either as word attachments to an email, or on disc. They should be sent to The Editors, Azra and Peter Meadows, The Glasgow Naturalist, DEEB, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland (email: <gbza31@udcf.gla.ac.uk> or <gbza21@udcf.gla.ac.uk>).

Papers and notes are refereed. Acceptance of articles and short notes is the responsibility of the Editors. The journal is published approximately yearly. Papers and short notes not presented in the format and style listed below will be returned to the authors for editing before they are refereed.

Papers and short notes are welcomed on any aspect of the natural history and ecology of Scotland, including freshwater, marine and terrestrial ecosystems and species, climate change and environmental management, botany, geology and zoology, field and laboratory studies, environmental engineering, socio-ecology, and historical treatments of ecosystems or natural historians.

2. Papers should be substantial accounts of scientific or related work. They should not exceed approximately 6000 words including references and equivalent space for tables and references. Longer articles must be discussed with the Editors before submission. Articles should be headed by the title, the author's name and address.

The text must be divided into sections with sub-headings as follows:

Abstract, Introduction, Methods, Results, Discussion, Conclusions, Acknowledgements, References.

3. Short notes should not normally exceed one page of A4 single-spaced. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new stations for a species, rediscoveries of old records, additions to records in the Atlas of the British Flora, unusual dates of flowering, unusual colour forms of plants or animals, ringed birds recovered, weather notes, occurrences known to be rare, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.

4. References in articles and short notes must be given in full (please do not abbreviate journal titles) according to the following style:

Pennie, I.D. 1951. Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.

Wheeler, A. 1975. *Fishes of the World*. Ferndale Editions, London.

Grist N.R. & Bell, E.J 1996. Enteroviruses. Pp. 381-90 in Weatherall, D.J. (editor) *Oxford Textbook of Medicine*. Oxford University Press, Oxford.

It is the **author's responsibility** to ensure that all references in the text are in the reference list at the end of the paper or short note, and vice versa.

5. Nomenclature of vascular plants should be as in Stace, C.A. (1997). *The new Flora of the British Isles*, (Second Edition) Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply. Use lower case initial letters for all common names e.g. wood ants, blackbirds, unless the common name includes a normally capitalised proper name e.g. Kemp's ridley. Where giving distribution information by vice-county, use the following style: VC 30.

6. Typescript font and font size. Papers and short notes should be presented in **Times Roman font size 10**, except for tables and figures which should be in Times Roman font size 9.

7. Tables and Figures must be supplied in electronic form as black and white. Please do not include them within the paper or short note. Place them at the end of the paper, or as separate files. They are numbered in Arabic numerals e.g. Table 1 or Figure 1. Figures and tables should be numbered separately. If a figure or table has separate parts it should be identified as 9 (a), 9(b) and so on. Use **Times Roman font size 9** for all contents of tables and figures. Each figure or table should have a legend. Figures and tables should preferably fit within one column of the journal. This means that they should be **less than 7.5 cm** in width. If this is really not possible they must fit within two columns of the journal and should be less than 15 cm in width. Figures are of two types. The first consists of graphs, histograms, scanned drawings, or flow charts. The second consists of black and white photographs. A metric scale must be inserted in micrographs etc. The Editors may able to accept a very small number of high quality colour photographs for each issue. Please consult the editors before submitting colour photographs.

8. Proofs One set of proofs will be supplied to the author in hard copy. It should be returned to the Editors by return of post. Alterations should be kept to the correction of typographical errors. More extensive alterations are not allowed.

9. Offprints. Ten offprints and one complimentary copy of the Journal are provided free of charge. Further copies may be purchased, provided that they are ordered at the time the proofs are returned.

10. Review. All submissions are reviewed by the Editors or their appointed referees. They are also assessed by the Editors or their appointed referees for ethical considerations.

Printed by Stirling Council's Reprographics Unit. 5054. Tel: (01786) 449899

The Glasgow Naturalist

Volume 24 Part 3 2005

Journal of
THE GLASGOW NATURAL HISTORY SOCIETY

GLASGOW NATURAL HISTORY SOCIETY

(formerly The Andersonian Naturalists of Glasgow)

The object of the Society is the encouragement of the study of natural history in all its branches, by meeting for reading and discussing papers and exhibiting specimens and by excursions for field work. The Glasgow Natural History Society meets at least once a month except during July and August, normally in the University of Glasgow.

The subscription rates in session 2004-5 were: for Ordinary Members, £21; Family Members, £5 extra; Student Members (under 21), £6; Children, £1.

Further information regarding the Society's activities and membership application forms are obtainable from the Membership Secretary, The Glasgow Natural History Society, c/o Zoology Museum, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland. The Glasgow Natural History Society website is http://www.gnhs.freeuk.com/, which also contains details of the Glasgow Naturalist.

The Glasgow Naturalist

The Glasgow Naturalist is published by the Glasgow Natural History Society. ISSN 0373-241X. Price £4.25 plus p. & p (as applicable at the time of posting). The Glasgow Naturalist is free to members.

Editors: Azra Meadows and Peter Meadows, Graham Kerr Building, University of Glasgow G12 8QQ (Tel: 0141 330 6622/6624, Email: gbza31@udcf.gla.ac.uk). (This volume only J.R. Downie, same address, Tel: 0141 330 5157, Email: j.r.downie@bio.gla.ac.uk).

Contributions are invited, especially when they bear on the natural history of Scotland. Full details of how to contribute articles or short notes are given at the end of the volume. A limited number of advertisements can be accepted and enquiries should be sent to the Editors.

This publication is included in the abstracting and indexing coverage of the Bioscience Information Service of Biological Abstracts and the Botanical Society of the British Isles Abstracts.

The following back numbers are available for purchase in their separate parts:

Vols.II-VII (1890-1918); Vols. XIII-XXIII (1937-1999).

Of the earlier Journals the only parts available are:

Proceedings and Transactions of the Natural History Society of Glasgow Vol. II pt. 2; Vol. VI pt. 1; Vol. VII, pt 3; Vol. VIII, pts. 1 & 2.

Enquiries regarding prices of and orders for any of the above, or for reprints or photocopies, should be addressed to the Librarian; contact address as above for the Membership Secretary.

Publications of Glasgow Natural History Society

Alien Species: friends or foes? Edited by J.R. Downie (2001). Proceedings of the GNHS 150th Anniversary Conference. Price £10.00 plus p. & p.

Bound copies of the following may be obtained from the Librarian at the address above and at the prices shown:

The Flora of the Clyde Area (Original printing). J.R. LEE, Price £11.00 to members of GNHS and to the book trade; £13.50 to others (plus p. & p.) This is still the only work of its type and is in diminishing supply. A few unbound copies are available; £5 (plus p. & p.).

The Flora of Ailsa Craig. B. ZONFRILLO, 1994. Price £2.50 plus p. & p.

The Natural History of the Muck Islands, N. Ebudes:

Introduction and Vegetation with a List of Vascular Plants. R.H. DOBSON & R.M. DOBSON, 1985. Price £1.00 plus p. & p.

Seabirds and Wildfowl. R.H. DOBSON & R.M. DOBSON, 1986. Price £1.00 plus p. & p.

Landbirds. R.H. DOBSON, 1988. Price £1.00 plus p. & p.

The following bound reprints from the *Glasgow Naturalist* may be obtained from the Librarian at the above address and at the prices shown.

Additions to the Flora of the Clyde Area. John R. Lee (1953). £1.00 (plus p & p.)

Archives

For archive information and special collections of the GNHS contact Karol Magee, Tel. 0141 287 2907.

Society Microscopes

The Society incorporates the Microscopical Society of Glasgow. Microscopes may be borrowed by members and are currently kept in the room of E.G. Hancock, Curator of Entomology, in the Graham Kerr Building, University of Glasgow.

Front Cover

Evening netting for salmon in Loch Lomond (photograph courtesy of Willie Simpson).

The Glasgow Naturalist
Volume 24 Part 3 2005

CONTENTS

The Glasgow Naturalist Volume 24 Part 3 Page 1 (2005).

THE NATURAL HISTORY OF LOCH LOMOND AND THE TROSSACHS CONFERENCE PROCEEDINGS

INTRODUCTION

Glasgow Natural History Society has had a long history of studying and enjoying the natural history of the West of Scotland. The Society celebrated its 150th Anniversary in 2001. The celebrations included a historical review of the Society's activities, published in the *Glasgow Naturalist* (volume 23, part 6, 2001) and a major conference on Alien Species, published as a supplement to the *Glasgow Naturalist* (volume 23 supplement, 2001). The conference was such a success that the Society's Council resolved to organise another one in the not too distant future.

In looking for a theme, Loch Lomond and the Trossachs came easily to mind. Under the National Parks (Scotland) Act 2000 the area was soon designated as Scotland's first National Park. An enquiry into the natural history of the Park seemed an obvious subject for a second conference (excursion list below).

In planning the conference, we were keen to blend the professional and the amateur. The study of natural history in the UK has long thrived on the work of enthusiastic amateurs, as well as professional biologists. One of the Society's major activities each year is a series of field excursions. As preparation for the conference, the 2004 excursion programme was dominated by visits to the Loch Lomond and the Trossachs area, and excursion leaders were invited to contribute to the Conference.

Another important aspect of the Society is our Blodwen Lloyd Binns Bequest fund, which awards small grants to natural history projects, especially in the West of Scotland. We were very happy, in the run up to the Conference, to be supporting several projects in the Loch Lomond and the Trossachs area, and to be able to call on the researchers involved to report their results to the Conference.

The Society has strong links with the University of Glasgow's Division of Environmental and Evolutionary Biology, based in the Graham Kerr Building, venue for the conference. The Division's Field Station lies at the heart of the National Park at Rowardennan, on the east side of the Loch. Several of the studies reported at the conference were based at the Field Station.

As well as reporting on the natural history of the National Park, we were keen to discuss policy issues. The legislation creates a difficult balancing act between the needs of conservation, recreation and development, and we were able to include contributions from two of the Park's staff plus an independent researcher on how these issues are being tackled.

Finally, in this introduction to the conference's themes, we must mention John Mitchell. John is well known for his role as ecologist at the Loch Lomond National Nature Reserve for many years, and for his recent (2001) New Naturalist series book on Loch Lomond. He has long been a member of the Society and has contributed frequently to the Glasgow Naturalist, including a series of articles under the heading Loch Lomondside depicted and described. John was a must for the conference, and we were delighted that he was able to accept our invitation.

These published proceedings are formal versions of the talks given at the Conference on 27th November 2004. Not everyone was able to provide a written version, and in some cases, fuller versions are being published elsewhere. The Society's web-site (http://www.gnhs.freeuk.com/llproceedings.html) has a more fully illustrated version of these proceedings.

Excursion programme in the Loch Lomond and the Trossachs area, 2004

(* = described at Conference, see written-up versions of talks, in these proceedings.)

17th April	Otter tracks, Gartocharn (Dominic McCafferty)
*1st May	Aberfoyle (Ian McCallum)
15th May	Insects at Rowardennan (Geoff Hancock)
*5th June	Kilmun (Bob Gray)
8th June	Balmaha (Hazel Rodway)
12th June	Millarrochy (Edna Stewart)
31st July	Callander's water meadow and Loch Ard forest (Joyce Alexander)
12th September	Bryophytes at Inversnaid (Keith Watson)
2nd October	Fungus foray at Inversnaid (Robin Jones)

ACKNOWLEDGEMENTS

We would like to thank Morag McKinnon for dealing with conference reservations and catering arrangements, Hazel Rodway for supplying copious amounts of tea and coffee on the day, Joyce Alexander for organising the excellent excursion` programme, Colin Adams for helping to chair the conference, and David Boyd for technical assistance with projection. The Society gratefully acknowledges financial help from Glasgow University's Institute of Biomedical and Life Sciences, Scottish Natural Heritage, and the Loch Lomond and the Trossachs National Park Authority.

Roger Downie
GNHS President 2001-4;
Conference Organiser
and co-chair

Richard Weddle
Proceedings editor

The Glasgow Naturalist Volume 24 Part 3 Pages 2-8 (2005).

INTRODUCTION TO THE LOCH LOMOND & THE TROSSACHS NATIONAL PARK

Alan Bell

Loch Lomond & The Trossachs National Park Authority, National Park Headquarters, The Old Station, Balloch Road, Balloch, G83 8BF.

The first part of this introduction is intended to help set the context for the conference, by providing some background on the National Park and the issues and activities in it. The second part looks at some aspects of the Park's ecology and issues relating to it.

The Loch Lomond and The Trossachs National Park became the first to be designated in Scotland when it was established on 8th July 2002. The National Park is in close proximity to most of Scotland's cities. Dundee, Edinburgh, Stirling, Glasgow are all within a drive of one hour or so of it.

It covers 186,340 hectares (460,440 acres), extending from The Holy Loch on the Cowal peninsula to St Fillans at the Eastern end of Loch Earn, and from Balloch to Tyndrum. The boundary extends to 350 km (220 miles). In broad terms the Park is comprised of four distinct areas.

- The "Argyll Forest" is centred around Loch Eck and the Firth of Clyde sea lochs, Loch Long, Loch Goil and the Holy Loch. The area is extensively afforested, with the great majority of the woodland falling within the Argyll Forest Park, owned and managed by the Forestry Commission

- "Breadalbane" is centred on Strathfillan, Glen Dochart and Balquhidder Glen, where the highest mountains are located. At 1174m (3821 ft), Ben More is the highest mountain in the park.

- Loch Lomond is the largest expanse of fresh water in Great Britain, with extensive oakwoods on its shores, many islands and surrounding hills including Ben Lomond.

- The Trossachs has numerous small to medium-sized lochs and intricate scenery. It includes Loch Katrine and the popular tourist attraction, the "Sir Walter Scott". It also holds extensive areas of forestry, much of it in the Forestry Commission-owned Queen Elizabeth Forest Park.

LAND OWNERSHIP AND LAND USE IN THE PARK

Significant parts of the National Park are in state ownership, especially by the Forestry Commission as well as Scottish Water, the Scottish Agricultural College and SNH. Other large areas are owned by public conservation charities the RSPB, National Trust for Scotland, Royal Scottish Forestry Society and Woodland Trust Scotland. The majority of the National Park is privately owned. The National Park Authority itself owns very little: mostly small parcels of land such as car parks and picnic areas at visitor facilities. In summary, 31% is publicly owned, 4.5% is owned by Charitable Conservation Organisations, 56% is in private ownership and 6.5% consists of water bodies.

Housing

The Park is home to a large number of people. The Park boundary runs through the middle of Balloch in the Vale of Leven at the north end of the greater Glasgow conurbation. Callander is the largest settlement in the Park, housing approximately 3000 people. In total , there are 15,600 residents within the Park. The majority of people live in a few large settlements but low-density residential housing is widely dispersed throughout the area.

Leisure And Recreation

The area is highly accessible from the major centres of population within the Central Belt resulting in high levels of recreational use by day visitors, and well as having considerable national importance as a tourist destination. Some three million people live within about 1 hour's travel of the Park. The development of infrastructure for visitors and the sheer numbers of people all have their impacts. The range of recreational activities brings about conflicting desires from different types of user. Fast, powered craft and quieter activities such as dinghy sailing or canoeing don't co-exist easily.

Transport

Two of the three trunk roads and one of the two railway lines from the central belt to the Highlands run through the Park. 85% of all visitors come to the Park by car. The majority of bulk freight is carried by road. In the eastern half of the Park, there are three significant dead end roads that attract their own difficulties of traffic management.

Vehicle pressure on the roads tends to lead to engineering solutions to bring improvements to traffic flow. Congestion on the A82 led to significant road works on west Loch Lomond side, with significant visual and landscape impacts. The highly visible sections by Inverbeg and the Firkin cut are extreme examples. However the trend continues.

Water Supply

The Park is also extremely important as a water supply, for hydro-electricity and drinking water. Loch Lomond and the reservoir complex at Lochs Katrine, Arklet and Finglas supply more than 1 million people, with 593 mega litres of water per day. Loch Sloy, Loch Venachar, Loch Arklet, and Glen Finglas reservoir are all substantially enlarged or entirely created by dams. Even in Loch Lomond, water

levels have been slightly raised by the construction of a barrage across the Rive Leven in Balloch.

The Sloy hydro-electric scheme came into operation in 1950. Sloy is the largest conventional hydroelectric power station in the UK. It generates 152.5 MW with 4 turbines, giving it twice the capacity of Scottish Hydro-electric's next most powerful conventional hydro-electric station at Errochty on the Tummel scheme. It can reach full load within 5 minutes of a standing start, making it ideal for use during times of peak demand.

Farming

A large proportion of the Park is used for farming, mostly livestock farming of cattle and sheep. Hill sheep are especially significant in both numbers and extent. In total there are 349 farms, covering 100,000 ha. 88,000 ha are rough grazing. About 4% of the local human population derive some income directly from farming. In 1993, the Park had 211,000 sheep and 14,700 cattle. In 2003 that had fallen to 165,000 sheep and 13,600 cattle.

The economic conditions in farming such as the introduction of single farm payments can be expected to continue the trend towards further reductions of grazing in the high uplands and conversion of lower reaches into forest. Over time, these changes will have consequential impacts on vegetation type and thus scenic properties.

Forestry

The National Park has 50,452 ha of woodland, consisting of:

- 34,307 ha conifer: mostly Sitka spruce- 80%, larch 8%, Norway spruce 5%
- 7,568 ha broadleaf; mostly birch-38%, oak 21%
- 5,550 ha open space in woodlands
- 3,027 ha mixed, felled, coppiced or windblown woodland.

Restructuring of the commercial plantations as the timber crops reach maturity is a major process on a truly industrial scale.

Minerals

The area has a long history of extraction of minerals for a variety of purposes. There are redundant quarries and mines for gold, lead and slate, with some conspicuous remnants such as the big slate quarries near Luss and Aberfoyle. There are also operational sand and gravel quarries at Callander. The Tyndrum Gold mine is currently mothballed but could re-open, depending on the price of gold on the international markets.

Field Sports

Angling for game fish, especially salmon and coarse fish, notably pike, as well as deer stalking are widespread in the Park. These are a significant income generator and employer in the smaller rural communities.

INTERNATIONAL CONTEXT

The wide range of economic and other activities in the Park make it comparable in many ways to other National Parks in Britain. Its context internationally is also worth considering. Clearly this National Park is not largely uninhabited or a wilderness as might be the case in many other Parks worldwide. IUCN, the World Conservation Union, defines six categories of "Protected Area".

I	Strict nature reserve/ wilderness area
II	National park
III	Natural monument
IV	Habitat / species management area
V	Protected landscape/ seascape
VI	Managed resource protected area

Category 2. "National Park" is defined as areas managed mainly for ecosystem protection and recreation. The selection criteria include that they should contain one or more entire ecosystems not materially altered by current human occupation or exploitation, and that ownership and management should normally be by the highest competent authority of the nation.

Category 4 areas are defined as being managed mainly for conservation through management intervention, with ownership and management by the national government. Scotland's National Nature Reserves fit partly into this category.

Category 5 areas are managed mainly for landscape/seascape conservation and recreation. They should possess a landscape of high scenic quality with diverse associated habitats, flora and fauna along with manifestations of unique or traditional land use patterns as evidenced in human settlements and local customs, livelihoods and beliefs. The area should provide opportunities for public enjoyment through recreation and tourism within its normal lifestyle and economic activities.

Category 6 areas are managed mainly for sustainable use of natural ecosystems. Selection criteria include that the area should be at least two thirds in a natural condition.

The Loch Lomond and The Trossachs National Park fits squarely into Category 5, as do the other UK National Parks.

STATUTORY PURPOSE OF NATIONAL PARKS IN SCOTLAND

The National Parks Scotland Act defines four aims that must all be delivered by National Parks in this country. In reverse order, these are:

Aim 4 To promote sustainable economic and social development of the communities of the area

Aim 3 To promote understanding and enjoyment of the special qualities of the area by the public, including enjoyment in the form of recreation

Aim 2 To promote the sustainable use of the natural resources of the area

Aim 1 To conserve and enhance the natural and cultural heritage of the area

Natural heritage is defined in the Act. It has three components:

- Natural beauty and amenity
- Geology and physiography
- Flora and fauna

NATURAL BEAUTY AND AMENITY

The National Park has a landscape of exceptional quality and diversity, which includes numerous large freshwater lochs, sea lochs, mountains, forest and open ground, supporting a rich diversity of plants and animals. The Park is renowned for its scenic beauty, and three areas have been designated as National Scenic Areas (NSAs) - one covering almost the whole of the Loch Lomond basin and surrounding hills, another is the core area of the Trossachs and a third the transition from lowland to highland at St. Fillans, Loch Earn. There is an exceptional variety of landscape types within the area, including:

- Vast expanses of water
- Rolling, relatively low-lying farmland on the more fertile soils along the southern margins of the Park
- Policy parklands and designed landscapes around big houses such as Rossdhu
- The contrast between these managed landscapes and the wild upland landscapes further north and west
- A significant stretch of coastline, 62 km long, around the fjordic sea lochs in the south west.

GEOLOGY AND PHYSIOGRAPHY

The National Park contains a wealth of geological features, including some of national and international importance. The Highland Boundary Fault that separates the Highlands from the Scottish Midland Valley across Scotland is the most well-known of these. Within the Park, the fault runs from Arden through Balmaha, Aberfoyle and Loch Venachar and its trace is clearly demonstrable within the islands of southern Loch Lomond.

The diversity of the Park's landscape derives from the effects of Highland Boundary Fault which divides the Park into two distinct regions with vastly differing soil types and topography.

Famously much of the current land form was created by glacial action but land form continues to be a dynamic process. A major thunder storm in August 2004 caused significant land slips in Glen Ogle and several other locations around the Park. Older scars from similar events can be seen on many other hillsides.

FLORA AND FAUNA

The flora of the Park ranges from the wide-spread and conspicuous features such as the bluebell-carpeted oakwoods to much less well known plants such as alpine bistort and purple saxifrage which are restricted to a few upland locations. Similarly the fauna ranges from widespread or familiar species such as badgers to much less well-known species like the freshwater peal mussel.

Priority species from the UK Biodiversity Action Plan that have been recorded in the Park are listed in Table 1.

Table 1: UK Biodiversity Action Plan species recorded from the Park

Latin Name	Common name	UK Distribution/ trend	Current Distribution in National Park
Mammals			
Sciurus vulgaris	red squirrel	Big decline in England & Wales in last 50 years. Recent modest expansion in range and number in Scotland.	Widespread
Lepus europaeus	brown hare	Decline in numbers since the early 1960s	Widespread in lowland areas
Arvicola terrestris	water vole	Catastrophic decline in range and numbers across UK	A number of discreet populations in the Park
Lutra lutra	European otter	Rapid decline in numbers from the 1950s to 1970s. Decline now appears to have halted and many sightings reported in former habitats.	Widespread
Pipistrellus pipistrellus *Pipistrellus pygmaeus*	pipistrelle bat	Significant decline in numbers this century. Recent discovery that there are two distinct species of pipistrelle bat in the UK	Widespread. Populations of the two pipistrelle species unknown
Birds			
Alauda arvensis	skylark	Declined by 54% in UK between 1969 and 1991	Widespread
Caprimulgus europaeus	nightjar	Decline in range of 52% between 1968 and 72 and 1992 in UK. Scattered populations in central Scotland	Patchy records of calling males
Crex crex	corncrake	75% decline in breeding population from 1968 to 1991	Occasional passage records
Carduelis cannabina	linnet	Declined by 56% on U.K farmland between 1968 and 1991	Small numbers in lowland areas of the Park

Emberiza schoeniclus	reed bunting	Decline in numbers in recent years	Widespread in suitable habitat
Melanitta nigra	common scoter	A rare breeding species in the UK	Irregular summer visitor
Miliaria calandra	corn bunting	Declined by 76% in UK from 1968 to 1991	Extinct in Park since 1970s
Muscicapa striata	spotted flycatcher	62% decline in woodland and a 70% decline in farmland in UK between 1968 and 1991	Widespread but scarce.
Passer montanus	tree sparrow	76% decline on UK farmland from 1972 to 1996	Recorded around Thornhill east of the Park.
Perdix perdix	grey partridge	75% decline in UK breeding population from 1968 to 1991	Very rare on farmland and moorland fringes.
Pyrrhula pyrrhula	bullfinch	75% decline on farmland and a 47% decline in woodland in UK between 1968 and 1991	Widespread in suitable habitat
Tetrao tetrix	black grouse	Recent UK population estimate (1996) is 6,510 lekking males compared with an estimate of 25,000 in 1990.	Declining in range and population size.
Tetrao urogallus	capercaillie	Declined rapidly throughout its range in Northern Europe over recent decades.	Breeding population of around 30 individuals largely confined to Loch Lomond islands
Turdus philomelus	song thrush	Declining throughout the UK	Widespread
Invertebrates			
Boloria euphrosyne	pearl bordered fritillary	Declined very rapidly over the last 50 years in the south of England. Still widespread in Scottish Highlands	A number of records from the NE area of the Park
Hydroporus rufifrons	a water beetle	Current status is unclear	Recorded from the Endrick mouth
Margaritifera margaritifera	freshwater pearl mussel	Most populations in Scotland no longer producing young	Evidence of small, ageing populations in some rivers in the Park, but not thought to be currently viable
Rheumaptera hastata	argent and sable moth	Declined throughout much of England	Unknown
Xylena exsoleta	Sword-grass moth	Substantial decline since the 1960s in UK. Still widespread in Scotland	Identified in four 10km squares
Vascular plants			
Athyrium flexile	Newman's lady-fern	Endemic to central Scotland, but now classified as a variety of the commoner *A. distenifolium.*	A few montane locations
Centaurea cyanus	cornflower	Major decline across Britain	One location
Cochlearia micacea	mountain scurvy grass	Restricted to basic soils in arctic–alpine sites	A few montane locations
Juniperus communis	juniper	Evidence of long-term decline in parts of UK	Widespread but patchy, showing little evidence of regeneration
Lycopodiella inundata	marsh club moss	Undergone a marked decline in the UK	A few localities
Melampyrum sylvaticum	small cow-wheat	Appears to be in decline	Found in Coille Coire Chuilc and around Ben Lomond.
Najas flexilis	slender naiad	Found exclusively in Scotland, where it has been recorded from 34 lochs within 18 ten km squares since 1980	Found in the Lake of Menteith
Pilularia globulifera	pillwort	Declining. Only recorded in 90 locations since 1970	Locations at Lochs Lubnaig & Lomond
Salix lanata	woolly willow	Occurs in only 12 locations in Scotland. All but one of these populations are very small (less than 100 plants)	Found at one location in the Park
Liverworts			
Marsupella stableri	a liverwort	No evidence of any widespread or substantial loss of its British populations over the past century	Stronghold in parts of Breadalbane hills
Lichens			
Catillarea aphana	a lichen	Recorded from only six localities in the UK	Recorded from one location on Loch Lomond-side.
Gyalecta ulmi	elm gyalecta	Recorded from six sites in Scotland	May occur just within northern boundary

Mosses			
Bryoerythrophyllum caledonicum	Scottish beard moss	Recorded from only 12 10 kilometre squares	Recorded from two Breadalbane locations
Ditrichum plumbicola	a moss	Endemic to Europe. Scattered distribution in UK	One record from Tyndrum lead mine spoil

Note. The table lists all priority species from the UK 1998 list which are recorded as occurring in the Park in the Interim Committee or Stirling Council Area Local Biodiversity Action Plan Audits.

DESIGNATED SITES

There are 61 Sites of Special Scientific Interest (SSSIs) within the Park area. Some of them are very large, like Ben Lomond, Ben More and Ben Vorlich.

Many SSSIs are also designated as Natura 2000 areas under European Directives. There are 8 Special Areas for Conservation (SACs) within the National Park, for the protection of rare, endangered or vulnerable natural habitats and species of wild plants and animals other than birds. Ben Lui and Meall na Samnha SACs are designated for their rare flora, including sub-arctic willow scrub. The Tay, Teith and Endrick Water are SACs for salmon and lampreys. These sites include several lochs and extensive stretches of riparian woodland as well as the rivers themselves. Loch Lomond Woods and Trossachs Woods SACs are designated for their Atlantic oakwoods. There is also one Special Protection Area (SPA) for wild birds; the Loch Lomond SPA which covers both the mouth of the Endrick Water with its overwintering Greenland white fronted geese and the Luss Islands with their population of capercaillie.

Many of the species and habitats mentioned above are widespread throughout Scotland. What aspects of the Park's biodiversity could be said to be truly distinctive?

LOCHS AND RIVERS

The numerous lochs and rivers in the National Park together form a tremendous nature conservation resource.

Loch Lomond is the largest area of freshwater in Britain, covering an area of 71 square kilometres and is 36 kilometres in length. The northern end of Loch Lomond is extremely deep, at around 180 metres.

Loch Lomond and Loch Eck are 'unique sites' in terms of the high diversity and unique combination of fish species present. There are nineteen species of freshwater fish in Loch Lomond including the largest of only two natural populations of Powan *Coregonus lavaretus* in Scotland, the other being in Loch Eck. Loch Eck is the only Scottish site where arctic charr and powan co-exist and the only British site where they co-exist with Atlantic salmon and sea trout. Powan have also been introduced to Loch Sloy to try and protect the species and extend their range.

The Trossachs lochs, including Achray and Venachar, hold several populations of arctic charr though some of these seem to have disappeared in recent years.

Also of particular note are the populations of lampreys. The presence of river, brook and sea lampreys is a qualifying feature for the Special Area for Conservation status under the Habitats Directive given to the River Teith and River Tay SACs.

The Endrick mouth, is a real biodiversity hotspot. It is an SPA for overwintering geese, a Ramsar site as a wetland of international importance and a part of the Loch Lomond National Nature Reserve. It holds a wide range of wetland habitats and associated species such as the Loch Lomond dock, a plant whose distribution in the UK is restricted to a few sites around Loch Lomond, as well as large numbers of breeding and overwintering waders and wildfowl. The River Endrick, from its mouth at Loch Lomond up to Fintry, is also an SAC for its river and brook lampreys and Atlantic salmon. Its river lampreys are unique in the UK in that they don't migrate to estuarine water to feed as adults but instead feed on powan and other fish in Loch Lomond.

Other significant wetlands are found in Strathyre, around Loch Eck and the north end of Loch Lomond.

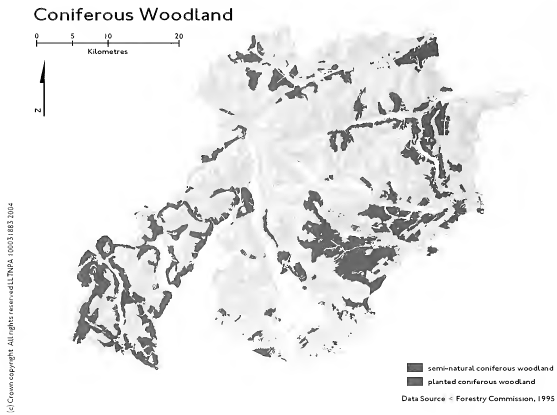
WOODLAND AND FOREST

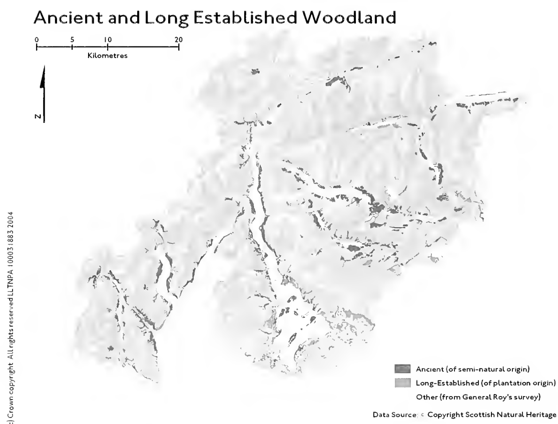
The Park has over 50,000 hectares of woodland and forest. The majority consists of productive commercial plantations, largely comprised of introduced coniferous species. Crucially the Park also has a very extensive native woodland resource. The relationship between the two is illustrated in the maps (Fig. 1) of coniferous woodland and ancient and long-established woodland.

Ancient woodland sites which were recorded as being semi-natural on the oldest maps (either the Roy maps from 1750 or the first edition Ordnance Survey from 1860), and have been continuously wooded since then, form 8.5% of the woodland cover of the National Park area. A significant proportion is underplanted with conifers but that is being steadily removed as restructuring of productive forests takes place. Very significant broadleaf woodland expansion is underway, particularly on east Loch Lomondside and at Glen Finglas, but also via the widespread development of a forest habitat network embedded into Forestry Commission plantations, particularly along riparian corridors. Extensive felling is in progress on the east shore of Loch Lomond for conversion to broadleaved woodland.

The Loch Lomond SPA includes the Luss Islands with their small remnant population of breeding capercaillie. The hope is that these birds will benefit from much of the woodland restructuring and improved woodland management now underway.

Fig. 1 Woodland areas in the National Park (see Endnote)





The scale of the Forestry Commission ownership, plus land under other owners sympathetic to nature conservation objectives means that a truly enormous native woodland resource is deliverable in the Park, while still allowing for very significant commercial timber production.

Oak Woodland

The Atlantic oakwoods on both sides of Loch Lomond are a candidate Special Area for Conservation (SAC) and are home to summer visitors such as redstarts, pied flycatchers and wood warblers.

Oak is the second most common broadleaf tree species as a result of its favoured status from the 17th to 19th Centuries. The Park contains an exceptionally diverse and extensive area of Atlantic oakwoods, representing a significant proportion of the Scottish total. The Loch Lomond Oakwoods form one of the largest areas of semi-natural woodlands in Britain.

Wet woodlands with trees emerging from seasonally inundated land are a feature in several locations around the Park

Pinewoods

The important remnants of ancient Caledonian pinewoods at Glen Falloch and Strath Fillan are perhaps the most 'natural' of the woodland types, though these suffer from a severe lack of regeneration due to past grazing pressures. These remnants are the most southerly surviving natural pinewoods in the UK. They occur very close to the natural transition point from pinewoods to oakwoods as the predominant forest type. The area of ancient native pinewoods is small (67 hectares), but there are several new native pinewood schemes now in place that will help in the long term to expand and reconnect this woodland type over much of its former range.

UPLAND AND MONTANE HABITATS

The occurrence of significant outcrops of limestone geology on the Breadalbane mountains create unusual alpine plant communities such as base-rich flushes and species rich tall herb communities that are rare in the rest of the Highlands.

The mountain massifs and upland areas of the Park contain remnants of heather moorland and montane scrub, and support a wide variety of bird species including golden eagle, peregrine, merlin, ptarmigan, twit, golden plover and, on some of the high tops, dotterel. The montane grasslands in the north of the Park are the main UK stronghold for the mountain ringlet butterfly.

The steep slopes with knolls, craggy gullies and cliff faces support many rare mosses, liverworts and lichens and extensive areas of snow-bed vegetation. Heaths, montane grasslands (many derived from heathland) and flushes have developed on the steeper slopes.

GRAZING MANAGEMENT

Perhaps the most significant issue in relation to both woodland and upland habitat management is that of grazing management.

There are a large number of red deer in the Park. Based on the most up to date deer group counts from 2000 and 2002, their total number in the Park is very approximately 10,000 individuals. This is probably a very high number in historic terms. The park also holds approximately 165,000 sheep, the great majority of which are hill sheep. This is a large decline from approximately 211,000 in the early 1990s.

More integrated control of deer numbers and a reduction in hill sheep have the potential to yield significant biodiversity benefits. In particular, if the practical difficulties can be overcome, there is the potential to reduce grazing pressure in some areas sufficiently to allow reductions in the extent of deer fencing around woodlands. This would allow a scrubby upper woodland edge to develop and form a more natural transition between woodland and open ground habitats with benefits for many species. Conversely, there is a danger that changes to agricultural support under CAP reform may lead to unpredictable effects such as abandonment of upland farming. Whilst this could yield benefits for some habitats like heather moorland or montane scrub species such as willows and juniper that favour lower grazing pressure, it may be less good for some birds such as ring ouzel and certain butterflies that favour shorter vegetation. A task for the Park will be to attempt to steer the effects, be they ecological, landscape or socio-economic, of such changes.

SELECTED LITERATURE

Argyll and Bute Local Biodiversity Partnership (1999). *Environmental Audit.*

Curran-Colthart, M., Holmyard, L., Sumsion, L. (eds) (2000). *Argyll & Bute Local Biodiversity Action Plan.* Argyll & Bute Local Biodiversity Partnership.

Central Environmental Surveys (2002). *Loch Lomond & the Trossachs Interim Committee Area Biodiversity Audit.* Unpublished Report to SNH and Interim Committee.

Central Environmental Surveys (2000). *Stirling Area Biodiversity Audit. Stirling Council.*

Department of the Environment (1994). *Biodiversity. The UK Action Plan. London*: HMSO.

Leaper, G. (1999). *Biodiversity of Tayside - A preliminary Assessment of Priority Habitats.* Tayside Biodiversity Partnership.

Loch Lomond & The Trossachs National Park Authority (2005). *State of The Park Report 2005.* Loch Lomond & The Trossachs National Park Authority.

Lloyd, C. A. (ed) (2002). *Tayside Biodiversity Action Plan.* Tayside Biodiversity Partnership.

Mitchell, J. (2001). *Loch Lomondside.* HarperCollins.

UK Biodiversity Steering Group (1995). *Biodiversity: The UK Steering Group Report Volume 2: Action Plans.* London: HMSO.

UK Biodiversity Group (1998). *Tranche 2 Action Plans. Volume 1 Vertebrates and Vascular Plants.* London, HMSO.

UK Biodiversity Group (1998). *Tranche 2 Action Plans. Volume 2 Terrestrial and Freshwater Habitats.* London,, HMSO.

Willet, J. *et al.* (eds) (2002). *The Stirling Council Area Biodiversity Action Plan. Volume 2.* Stirling Council Area Biodiversity Action Plan Steering Group.

Endnote:

Mapping Sources: the maps in this article were produced for the Loch Lomond and The Trossachs State of The Park Report during 2004 and 2005 and are reproduced with the permission of LLTNPA. Representation of features are indicative only. All maps are based upon Ordnance Survey material and are (c)Crown copyright 2005.

Coniferous woodland data are derived from the National Inventory of Woodland and Trees 31/03/1995: Forestry Commission Scotland. Ancient and long established woodland data are derived from the Inventory of Ancient and Long-established Woodland Sites: Scottish Natural Heritage.

The Glasgow Naturalist Volume 24 Part 3 Pages 9-12 (2005).

NATIVE BROAD-LEAVED WOODLAND ON LOCH LOMONDSIDE -- THERE IS MORE THAN JUST OAK

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 0DX

SUMMARY

The celebrated oak woods of Loch Lomondside have attracted a number of historical and ecological studies. This contribution to the proceedings highlights the presence of other broad-leaved woodlands, which to date have received far less attention.

INTRODUCTION

The bonny banks of Loch Lomond are nationally, if not internationally famous for their oak woodlands, be it the remaining stands of the indigenous sessile oak *Quercus petraea,* or the commonly found hybrids which have come about through the practice of planting pedunculate oak *Q. robur* introduced from the south. Before the development of synthetic tanning agents, almost all of the oak woods in west central Scotland had been drawn into the production of bark essential to the leather trade in Glasgow and elsewhere. Coppicing the Lomondside oaks at regular intervals for their tan bark came to an end around the turn of the 20th century, the trees being allowed to resume uninterrupted growth towards the semi-natural high forest we are familiar with today.

Readily accessible, these former industrialised stands of oak on Loch Lomondside have become the most comprehensively studied by historians and ecologists of any in the country, but to the neglect of other species of broad-leaved trees present which together make up an equally important part of the region's woodland heritage. The present paper draws attention to some of these less well documented woodland types.

Fig. 1. Enclosed in the 1960s, the once virtually treeless hillsides of upper Glen Douglas now show a prolific expansion of self-seeded birch.

UPLAND PASTURE BIRCH WOODLAND

Beset by oceanic winds and heavy rains so characteristic of the mountainous West Highlands, the Lomondside oak woods running up from the loch-side begin to peter out well before the 300 m contour is reached. Birch *Betula pubescens* on the other hand is better suited to the poorer growing conditions of the higher slopes, with trees found up to the 450-500 m mark. However, unlike the birches within the enclosed low ground - which formerly had economic worth by providing tan bark or its wood used in the manufacture of thread bobbins - the trees growing above the protection of the head dyke have been continually subject to browsing by red deer *Cervus elaphus,* cattle, sheep and feral goats over a long period. As a result, regeneration of these upland stands has to a large extent been held in check. In one extreme case a presumed ancient high-level birch wood in upper Glen Falloch, which was investigated and described less than a hundred years ago, has since entirely disappeared.

Where these former hill grazings have been securely fenced against deer and domestic animals, the scattered remnants of this high level birch woodland have shown a remarkable capacity to recover and regain lost ground. Nowhere is this demonstrated more clearly than the Ministry of Defence's property at the head of Glen Douglas. Together with rowan *Sorbus aucuparia*, goat willow *Salix caprea*, etc., a covering of birch has spread over large areas of the enclosed land in less than half-a-century (Fig. 1).

HOLLY UNDERSTORY

The evergreen holly *Ilex aquifolium* is a familiar shade-tolerant shrub or small tree occurring in most of the Lomondside oak woods. In the past, the fine-grained wood obtained from mature holly was much in demand for making the patterned blocks used in the hand printing of designs on linen and cotton, before the wood carver's art was gradually displaced by the engraved copper cylinder which greatly increased the output of printed cloth. A major source of holly for the Vale of Leven's textile print works was the Parish of Luss, almost certainly from the 'Forest of Hollies' near Aldochlay as shown on Charles Ross's 1777 map of the Colquhoun Estate. Regrettably, only a few of the surviving old trees (Fig. 2) escaped the recent felling which took place during the construction of a bypass to the village of Luss.

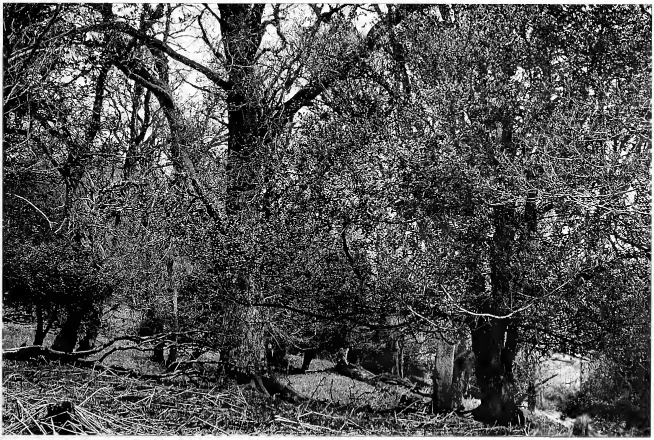


Fig. 2. A few veteran hollies are still to be found at Aldochlay near Luss.

Fig. 3. Secondary growth from trees felled in the past is typical of Loch Lomondside's alder woods.

Fig. 4. In standing water for prolonged periods and only ever partially drying out, flood willow has become one of Britain's most uncommon woodland types.

Deer are especially partial to unhardened holly seedlings, and in the open Aldochlay woods no successful regeneration appears to be taking place. This contrasts with the encouragingly large number of young hollies springing-up inside the Forestry Commission and the National Trust for Scotlands' woodland enclosures between Rowardennan and Ardess on the east side of the loch.

ASH AND WYCH ELM MIXED STANDS

Whereas birch and holly can be found scattered throughout the Lomondside woodlands, mixed stands of ash *Fraxinus excelsior* and wych elm *Ulmus glabra* are confined to where there are pockets of mineral-flushed soils. Ash can be seen to advantage in some of the red sandstone ravines, alongside streams and in particular below the crumbling calciferous cementstones exposed in the Scottish Wildlife Trust's reserve at Ballagan Glen. But for an area that was once known as *Leamanonius Lacus* – or Lake of the Elms – today on Loch Lomondside the wych elm is decidedly scarce. Although elm timber had a number of marketable qualities, it was evidently not profitable enough for woodland managers to ensure young trees were planted as replacements for those taken out.

With growing on the more calcareous soils, ash and wych elm are understandably often associated with the presence of a rich ground flora, such as occurs on Creinch in the Loch Lomond National Nature Reserve administered by Scottish Natural Heritage. This small island's plant list includes several species which have few other known localities in the Clyde area.

ALDER WOODS OR CARR

The moisture-loving alder *Alnus glutinosa* is widespread throughout the lower ground wherever drainage water gathers towards the bottom of a slope. Linear stands can also be found in many places along the periodically inundated shore zone of the loch. On examination, it soon becomes apparent that virtually every one of the region's alder woods is made up of multi-stemmed re-growth from cut stumps (Fig. 3), with few if any untouched maiden trees. Writers on woodland history never fail to mention that alder was the first choice for conversion to the high-grade charcoal necessary in the production of gun powder, but on Loch Lomondside it is more likely that most of the trees were cut by 19th c. 'cloggers'. These itinerant bands of woodcutters harvested the water-resistant material for making the wooden soles of cheap and durable footwear much favoured by mill and factory workers.

Field observations on Lomondside's introduced population of fallow deer *Dama dama* have shown that the animals appear to find alder unpalatable, which would account for the alder's dominance over other tree species in some areas of the one-time fallow deer parks on two of the islands in the loch - Inchlonaig and Inchmurrin.

FLOOD WILLOW WOODLAND

Located at the interface between land and water, where flooding from river or loch is a regular occurrence, grey willow *Salix cinerea* ssp. *oleifolia* – interspersed with alder, birch and occasional oak – dominates this primeval-looking woodland (Fig. 4). The few examples present on Loch Lomondside today represent the last vestiges of an alluvial forest that must have covered large tracts of the region's low-lying flood plains before agriculturalists began clearing away the trees and draining the land to exploit the rich productive soil.

Supporting a wealth of marsh/aquatic flora and fauna, which includes species with very restricted distributions in Britain, the most extensive stand of flood willow beside the lower reaches of the River Endrick has an especially high conservation value. Like Creinch, these woodlands form part of the Loch Lomond National Nature Reserve.

ACKNOWLEDGEMENTS

Thanks are due to Norman Tait for the preparation of the author's photographs accompanying this paper.

FURTHER READING

Mitchell, J. (2001). *Loch Lomondside: Gateway to the Western Highlands of Scotland* (New Naturalist No.88). Harper Collins, London.

The Glasgow Naturalist Volume 24 Part 3 Page 13 (2005).

LONG-TERM CHANGES IN THE MOTH ASSEMBLAGE OF EAST LOCH LOMOND-SIDE: 1968 – 2003

Nabeil Salama, John Knowler & Colin Adams*

University Field Station, Institute of Biomedical & Life Sciences, University of Glasgow, Rowardennan, Glasgow G63 0AW, UK

During the period of 1968 to 2003, moths were caught daily in a Rothamsted light trap located on east Loch Lomondside and operated by the University Field Station. Lepidoptera are a large group of phytophagus insects that have many roles in a natural community and are important indicators of varying climate and land-use change, therefore knowledge of altering community is useful in ascertaining the impact anthropogenic activities are having on the natural ecosystem. Analysis of catch data indicates that there was a significant increase in numbers of individual macro-moths recorded (from a mean of 8,250 in 1968 to 12,863 in 2003) representing a 56% increase in macro-moth abundance. The number of species also increased, from a mean of 137 in 1968 to 188 in 2003 (a 37% increase).

Within the community, three of the five most abundant species, the Northern spinach *Eulithus populata*, July highflier *Hydriomena furcata* and the Small fan-footed wave *Idaea biselata*, showed significant increases in numbers.

The remaining two species, the November moth *Epirrita dilutata* and the Mottled umber *Erranis defoliaria*, however showed no change in abundance. Although average annual air temperature in Scotland has increased over this 35 year study period, air temperature did not predict changes in macro-moth species diversity or abundance. Two of the most abundant moth species, the Northern spinach and the Small fan-footed wave showed evidence of earlier emergence times but no evidence of increased flight periods (the time from first to last recording). The July highflier showed evidence of both earlier emergence and longer flight periods over the 35 year study period. The November moth showed no change in either emergence time or flight period. Overall we conclude that dramatic changes in macro-moth abundance and diversity on east Loch Lomond is not the result of simple temperature change but more likely the result of a combination of the stability of the habitat at this site plus possibly more subtle climate change effects.

A detailed account of these results is being prepared for publication elsewhere

* author for correspondence

The Glasgow Naturalist Volume 24 Part 3 Page 14 (2005).

ALIENS AT KILMUN: A FUTURE FOR ECOSYSTEM MANAGEMENT?

Bob Gray
c/o GNHS, Zoology Museum, Graham Kerr Building, University of Glasgow G12 8QQ

The 120 acres of Kilmun Forest Garden comprises part of Argyll Forest Park, in 1935 the first such park to be established in the UK. It now forms part of Loch Lomond & the Trossachs National Park, located in the far southwest corner of the recently established entity. The Garden itself was established in 1930 as a site for experimental tree planting by the Forestry Commission. Among the factors that encouraged this choice were the mild oceanic climate, the annual rainfall of c. 200 cm. (80") and very rare frosts.

The existence of the Kilmun plots has been one of the Forestry Commission's best-kept secrets. In 1960 an Edinburgh University forestry department silvicultural tour of the UK included a visit to nearby Benmore but no reference was made to Kilmun. Perhaps this was not entirely surprising in view of the fact that most of the lessons to be learned about silvicultural practice came from the early introductions and experimental plantings carried out during the 19th and earlier centuries by various Scottish landowners. The Forestry Commission had been set up in 1919. Kilmun Arboretum was planted in groups to test a variety of trees under forest conditions but the demand for forest expansion could not wait the 40 or so years necessary for the research results. However as an educational and recreational site the area is hard to beat.

The site has a southwesterly aspect and the trees were planted in groups from 20 to 300 metres a.s.l. The underlying bedrock comprise Dalradian quartzose mica schists giving rise to free draining brown earths on slopes and gleying where the ground levels out. Open spaces are rapidly colonised by native bracken, which reduces floral diversity. Group planting (plots) is what distinguishes Kilmun from arboreta, where tree species tend to be planted singly, or woods, where large numbers are planted together. Native species were not planted since until recently their potential for timber production in Scotland was not taken seriously.

260 species from 50 different genera and of different provenance were planted between 1930 and 1985. Conifer genera adapted to the moist oceanic climate have done best whereas genera such as pines have done less well. High growth rates have been shown by silver firs, especially *Abies amabilis, A. grandis* and *A. procera*, as well as Japanese cedar (*Cryptomeria japonica*), Leyland cypress (*Cupressocyparis leylandii*), coastal redwood (*Sequoia sempervirens*) and giant sequoia (*Sequoiadendron giganteum*). Broadleaved survival and performance have been poorer than that of conifers but exceptions include Oregon maple (*Acer macrophyllum*) and Chilean southern beech (*Nothofagus procera*). These species, especially where shade bearing, could be used to convert single species forests to mixed forests where appropriate.

Next door to Kilmun and linked to it by means of a track is Benmore forest. Opposite the entrance to the arboretum the society members climbed a steep path that took us high into the canopy of the developing woodland that comprised coastal redwoods, giant sequoia, grand firs, western hemlocks (*Tsuga heterophylla*), western red cedars (*Thuja plicata*), Douglas firs (*Pseudotsuga taxifolia*) and others. Beneath these towering giants pirri-pirri burr (*Acaena novae-zelandiae*) was growing. Towards the top of the path a massive windblown European silver fir (*A. alba*) had fallen over the track and a footbridge has been built over it providing a good view of natural regeneration of Douglas fir in particular. This emphasises how well adapted many alien trees are to climatic and soil conditions in this country.

Factors such as continental drift, east-west mountain ranges and the ice ages have deprived Britain of all but a fraction of an impoverished North European flora. Our latitude provides long light in the growing season and the gulf stream provides higher temperatures at these latitudes than elsewhere in the world and so not only is a large number of exotic trees available for planting here but also many trees grow better here than they do in their native habitats. (Hence the existence of the International Conifer Conservation Programme, planting groups of endangered species on 130 sites throughout the UK, including 12 such conifer species at Kilmun). This is not to denigrate the outstanding work being done by Forestry Commission Scotland, the Royal Scottish Forestry Society, the RSPB and others on the eastern shore of Loch Lomond, in the re-establishment of indigenous oak woodland, but to draw attention to the eminent suitability of many exotic conifers to British environmental conditions. Increasing the number of exotic plantings will increase the biodiversity of the British countryside and the number of ecological niches available for the success of increasing numbers of plants and animals.

The spectacular Chilean fire bush (*Embothrium coccineum*) at the entrance to Benmore demonstrates how alien species can add to our enjoyment of the environment. It is worth bearing in mind that the giant sequoias forming the avenue are mere juveniles, planted in 1863. Already there are twice as many of these trees having a girth greater than 20' than oak trees of such a girth in the country. If this continues the biggest trees in the British Isles will be completely dominated by this species. We've come a long way since Dr. Samuel Johnson wrote in 1773 that 'a tree in Scotland is as rare as a horse in Venice'.

This year as it happened FC Scotland has commissioned a feasibility study to look at the future development of the arboretum. The proposals fit in with the likely policy framework of the first Park Plan. Amongst these proposals is the promotion of the arboretum's scientific record and its potential as a tree collection of international note to a local and international audience. The Society's visit to Kilmun was indeed a timely one.

The Glasgow Naturalist Volume 24 Part 3 Pages 15-16 (2005).

GLASGOW NATURAL HISTORY SOCIETY EXCURSION TO ABERFOYLE

Ian McCallum

c/o GNHS, Zoology Museum, Graham Kerr Building, University of Glasgow G12 8QQ

This is an account of a combined outing of the Glasgow Natural History Society and the Edinburgh Natural History Society to the Aberfoyle area on 1st May, 2004.. As part of the Loch Lomond and Trossachs National Park celebration year, it was decided to have some of the Society's outings within the National Park.

The members (Fig. 1) met at 11.00 hrs at the Woollen Mill in Aberfoyle, where sustenance was available. Outside the Mill there was a display of birds of prey and a collection of sheep including a magnificent 4-horned ram. The party, which comprised 9 Edinburgh and 5 Glasgow members, was given a short description of the excursion before setting off. Thanks were given to Sandra Stewart and Kathleen Rowdon for agreeing to make lists of botanical species. The route followed the Glasgow to Aberfoyle disused railway line to Cobleland, returning to Aberfoyle on the other side of the River Forth via Robert Kirk's church.

The sun was shining and bird song was much in evidence. Swallows, house martin, willow warbler, robin, chaffinch, greenfinch, blackcap, stonechat and jay were seen or heard. Some of the best views were on the river, where we had good sightings of dipper and goosander. Along the banks of the River Forth were animal tracks, and the leader illustrated a method of recording tracks using overhead projector film and drawing the tracks on the overlay. On the path the party found the maze-gill fungus *Daedalea quercina* on oak and further on a song thrush's anvil surrounded with the broken shells of its last meal. Spring flowers were everywhere. Areas of mature woodland were carpeted with wood sorrel *Oxalis acetosella*, wood anemone *Anemone nemorosa* and wild hyacinth *Hyacinthoides non-scripta*. Alongside the track was a succession of flowers including three-veined sandwort *Moehringia trinervia,* germander speedwell *Veronica chamaedrys* and golden saxifrage *Chrysosplenium oppositifolium.*

Fig. 1 The excursion group

A short talk was given describing the geology of the area. The Highland Boundary Fault runs from Stonehaven in the east to Arran and beyond in the west. It runs through Aberfoyle, and at Dounans quarry a wedge of limestone has been exploited. This limestone has fossils of trilobites, brachiopods and ostracods, which date the rocks to 475 Ma (Ordovician Period). These fossils, together with fossils found in the Bofrichlie Burn, are the same as North American fossils, which prove that the Highlands were connected to North America. At that time there was no Atlantic Ocean, no North Sea and an Ocean called Iapetus separated Scotland from England and Wales. The Iapetus Ocean closed by the end of the Silurian Period (405 Ma) when Scotland and England were joined due to Tectonic Plate movements. South of the fault are Old Red Sandstone (Devonian period - 400 Ma) conglomerates, formed by large rivers flowing from the North and the South. The red colour is due to the oxidisation of iron, which presumably took place during periods of high temperature. To the north of the fault lie the older Highland rocks. During the Ice Ages that followed, the action of the ice sheets had a major effect on the scenery. The ice stripped the rocks and soil from the hills and when the ice melted, dumped the morainic material in the valleys.

Butterflies were also abundant – mostly Orange Tip, Peacock, Small Tortoiseshell and Green Veined White. On the bridge over the Forth there were the ferns Wall Rue *Asplenium ruta-muraria* and Common Maidenhair Spleenwort *Asplenium trichomanes*.

After walking through the caravan park the group had lunch on the banks of the Forth. The sun shone warmly and after lunch the party reluctantly moved off but only after a common sandpiper had been watched and a longhorn type of wood beetle had been closely examined. The members continued following the Forth upstream past banks of primroses *Primula vulgaris*, sweet smelling Balsam poplars *Populus trichocarpa*, geans *Prunus avium*, and stopped at a fine example of a Douglas fir *Pseudotsuga menziesii*, where the diagnostic features were described – the citrus smell of the crushed foliage and the three-pronged bracts that resemble a trapped mouse under the cone scales.

Before moving on to the last stop at Aberfoyle Auld Kirk, the party visited the top of Doon Hill where messages to the fairies were read. At the Kirk, mortsafes were examined and Robert Kirk's grave inspected. Robert Kirk was the fairy pastor who translated the psalms into Gaelic and wrote The Secret Commonwealth, which dealt with the second sight and the fairies. The question was, did Robert Kirk lie under the gravestone, or was he still in the world of the fairies? In the car park there was an interesting information board on the Bailie Nicol Jarvie of Rob Roy fame and his poker still hangs from the tree. The parties returned to their transport about 16.15 hrs. Most then disappeared into the Woollen Mill for a rejuvenating cup of tea prior to heading home.

The Glasgow Naturalist Volume 24 Part 3 Pages 17-22 (2005).

RECREATION IN THE LOCH LOMOND AREA: ECOLOGICAL AND PERCEPTUAL DIMENSIONS

Gillian Dalrymple
Department of Geographical and Earth Sciences, University of Glasgow, Glasgow G12 8QQ

ABSTRACT

The recent implementation of Loch Lomond and the Trossachs as Scotland's first National Park heralds an exciting time for outdoor recreation in Scotland. Recreation involves the sharing of countryside resources and should be viewed in balance with environmental conservation. The aim of the paper is to address this balance, integrating the ecological, behavioural and perceptual dimensions of recreation. Based on field work completed by the author in 2003/2004, the paper focuses on recreation in the Loch Lomond area. Qualitative and quantitative methods have been used to implement this research; namely interviews, questionnaires, systematic observation, documentary evidence and ecological surveys. A variety of econometric models have been created, including a travel cost model and a contingent valuation model, both created in order to value trips to the study area. Based on these models a 'typical' day at Loch Lomond is valued at £20.53, with visitors willing to pay an extra £1.76 to fund environmental improvements. Looking at the particular environmental issues of noise, crowding and environmental damage, noise pollution appears to have the greatest influence on recreation enjoyment. Policy implications, including the implementation of a possible parking fee at various sites around Loch Lomond, are addressed. In conclusion it appears that a sustainable approach to recreation management, one which is based on the outcomes of the above econometric analysis and one that encompasses the perceptual and ecological dimensions of recreation, is the only way of maintaining the beauty and enjoyment of national parks for future generations.

Keywords: recreation, national parks, Loch Lomond.

INTRODUCTION

In July 2002 the Loch Lomond area was designated as part of Scotland's first National Park: the Loch Lomond and The Trossachs National Park. This designation heralded an exciting and dynamic time for recreation and tourism in Scotland. As a consequence of National Park status there has been a rising demand for recreation activities in the Loch Lomond area (popular recreation activities in the area include walking, hiking, boating, jet skiing, picnicking and so on). This may lead to two fundamental pressures: higher visitor numbers may lead to overcrowding at certain sites, and reduced utility per visit; and secondly, higher visitor numbers may place more pressure on the natural environment. Sustainable environmental and recreational management is therefore a must: never has there been a greater need for recreation research to inform environmental policy. My research hopes to inform policy for the National Park area, while at the same time expanding academic knowledge through the integration of the ecological and social impacts of recreation.

Specifically, the aims of my research are four-fold: (1) to study recreation in the Loch Lomond area, focussing on the water and the associated lake margin environment; (2) to determine the more important factor to the 'typical' Loch Lomond visitor, namely: perception and the social dimensions of recreation (crowding, noise, visitor conflict) or the actual environmental conditions of a site; (3) to investigate whether visitor perception of environmental damage differs from the actual levels of environmental damage, again focussing on the water and associated lake margin environment; and (4) to integrate perceptual and ecological findings in order to recommend future resource and recreation management options. My study sites are the outdoor recreation areas of Milarrochy Bay, Rowardennan and Sallochy on the east shore and Firkin on the west.

Located in the southern Scottish highlands, Loch Lomond is the largest inland waterbody and largest stretch of freshwater in Great Britain (it is 23 miles long and up to five miles wide). At its closest point it is no more than thirty kilometres (eighteen miles) from Glasgow, the most populated city in Scotland. This favourable location, high accessibility and great scenic beauty make Loch Lomond an important recreational, scientific and economic resource; and the centrepiece of Scotland's first National Park. Tourism has become a mainstay of the local economy; indeed it is estimated that around three million visits are made to the Loch Lomond area annually. It is interesting to note that the Loch Lomond and Trossachs area is the most popular countryside area for tourism in Scotland as measured by the number of visits made (Dickinson, 1996) and it is expected that as the National Park becomes increasingly well-known, demand for tourism in the area will continue to increase. However, rising visitor numbers imply greater pressure on the natural environment itself: a balance between a sustainable environment and tourism/recreation pressure must therefore be found.

Indeed, the Loch Lomond area already faces a number of environmental and social issues as a result of the high influx of tourists into the area. Three such problems, which are addressed in my research, are high noise levels (where personal water craft "jet skis" are present), crowding and environmental damage. The last of these issues, the environmental impact of tourism, has been widely addressed in the literature (see for example Tivy, 1980; Murphy et al, 1994; Bannan 1999; and Hanson, 2000). Environmental impacts prominent in the Loch Lomond area include the erosion of beach and back-shore areas, trampling of vegetation, litter, the introduction of non-indigenous fish species, and water pollution. These problems are

compounded by two factors: access issues and a concentration of leisure use in time (Dickinson, 1994).

It is likely that more than 90% of all visits to Loch Lomond are by car (Dickinson 1996), however, car access is restricted to a relatively limited area in which car parking and suitable sites for recreation are available. For this reason environmental impacts, crowding and high noise levels are particularly high in areas where car access to the Loch shore is present. The survey sites of Rowardennan, Sallochy, Milarrochy Bay and Firkin are examples of such 'honey-pot' sites. There is therefore a concentration of visitors in space.

Secondly, there is a concentration of visitors in time. About 75% of all visits to the Loch Lomond area are made on Sundays, with most of the rest occurring on Saturdays. This is compounded by weather, summer season and public holidays (Dickinson 1996). Thus, although average use levels may not seem to be within physical capacity, it is during the periods of peak use, which occur on only a few days throughout the year, when environmental and social issues are most prominent. It is these periods of peak use that require careful recreation management.

The overall pattern of recreation impact in the Loch Lomond area, incorporating the problems of noise pollution, overcrowding and environmental damage, can thus be summarised as being of limited spatial extent but of significant degree in affected sites. It is important to note that tourism and recreation are not the only land-uses prominent within the National Park boundaries: agriculture, forestry, conservation and hydro-electric power also exist as land uses in the area. In addition many people live and work in the Park. Integrated management is clearly needed in order to protect the total resource base of the area.

METHODS

A 'multi-methods' approach has been used to implement my research. Qualitative and quantitative methods are combined. I've conducted interviews (semi-structured) with managers from the Park Authority and the Forestry Commission, and also with jet-skiers, local businesses, sailors and anglers. All interviews with management were qualitative and in-depth and lasted approximately one-hour. Interviews with jet-skiers, local businesses, sailors and anglers lasted anywhere from fifteen minutes to half an hour.

A Questionnaire survey was constructed and issued, on-site, to Loch Lomond visitors. Initially a pilot survey was undertaken in summer 2002. Here 60 questionnaires were issues over four survey days at Milarrochy Bay and Sallochy. The main survey was then undertaken in Summer 2003. 548 responses were obtained over 24 days and two evenings. The survey was distributed at the four sites of Rowardennan, Milarrochy Bay, Sallochy and Firkin. As the questionnaire was issued as an intercept survey (i.e. face-to-face on site) there was a 98% response rate; those refusing to answer the questionnaire did so primarily due to lack of time. Respondents were asked questions relating to their socio-economic characteristics; their origins; their recreation activities; their perception of the presence (or absence) of crowding at a site; their perception of noise pollution; and their perception of the environmental conditions (specifically litter, dead trees, water pollution, exposed tree roots, broken branches, shore erosion and vegetation trampling and then environmental damage in general).

On the days that the questionnaires were issued observation was also made of visitor behaviour, appearance of the site and recreation activities; and recorded in the form of field notes. This is known as 'systematic observation' and as such an observation schedule was developed. Direct data collection was implemented through recording what people do, as distinct from that that they say they do. Photographs were made of each site, with the basic purpose of establishing the visual use and character of the area. A systematic observation of environmental damage at each site was made using a quantitative checklist, for example: are exposed tree roots present? Yes or no. A visual assessment of visitor damage was also made, where the aim was to establish the level of visitor impact around the entire length of Loch Lomond. This was carried out in July 2004 by boat. Using a six-point scale of visitor damage I mapped GPS positions and the points where visitor damage level changed. My visitor damage survey is based on a six-point visual assessment scale; from one (no evidence of visitor impact) to five (evidence of very high visitor impact), plus category six (artificial/highly modified or rock shoreline).

Documentary Evidence (for example newspapers to boat users and information leaflets to visitors to Loch Lomond) has also been looked at. In addition newspapers on jet-ski use in Loch Lomond have been monitored. This will help determine whether the information available influences visitor perception.

A more detailed scientific ecological survey was undertaken at eight selected sites in and around Loch Lomond in order to look at the impacts of recreation on plant frequency. Each site was sampled at six-week intervals throughout summer 2003 (including Ardlui (North), Inverbeg (North-West), West Highland Way (North-East), Sheltered Bay (North), Narrows (South), Bay at Golf course (South-West), Milarrochy Bay (South-East) and Camas an Losguinn (South)). Both the field and shoreline plants and the aquatic macrophytes were sampled. In order to meet scientific requirements environmental variables were also measured at each site including soil redox (using a soil redox meter), underwater light availability (using a light sensor meter) and substrate type.

RESULTS AND DISCUSSION

Some 70% of the 548 questionnaire respondents were in the 25 to 54 years age bracket. 12% and 18% of respondents were in the age brackets under 25 years and over 54 years respectively. There was a relatively even split between male and female interviewees, with 52% of respondents female and 48% male. The mean household income was around £37,000 ($69,460) (somewhat higher than the Scottish mean of £26,988, $50,686). A very large percentage of respondents, 92%, arrived at the site by car and while 61% were day-trippers, only 39% were tourists. Of those stating that they were tourists the majority stayed for only one to three nights, with 16% of tourists passing through Loch

Lomond and only stopping at a site to view the Loch before continuing to their accommodation outwith the National Park area. In terms of participation, the mean number of trips made in the previous twelve months was six (with a maximum of thirty trips) and 96% said they would return to the Loch Lomond and Trossachs National Park area in the future. Reasons for this return included to see more of the National Park and to undertake further recreation activities. 72% of respondents carried out "passive" activities such as picnicking or sitting or walking near the shore, as opposed to "active" use such as mountain biking or boating. The average length of time spent on site was two hours, and the mean group size was 3.02. 51% said activities undertaken by other people typically reduced their enjoyment of a day out on Loch Lomond; 63% of respondents believed that jet skis caused noise pollution; only 7% believed they caused water pollution. 81% said noise pollution affected the enjoyment of their visit; 80% said that crowding affected the enjoyment of their visit; and finally 79% said that environmental damage affected the enjoyment of their visit.

In order to analyse the results of the questionnaire survey further, with greater detail, econometric models were created; namely a travel cost model (TCM), a contingent valuation model (CVM) and contingent behaviour models (CBMs). I will only discuss two of these models here: TCM and CVM.

Initially, using the results of the questionnaire surveys the TCM was created. TCMs try to infer the value people place on environmental goods from their actual behaviour. It was set up in order to predict recreation demand for visits to Loch Lomond and to estimate consumer surplus (CS) per trip under current site conditions. Consumer Surplus is the difference between the most a visitor would pay (per trip) and what they actually pay (Hanley et al, 2003). It provides a monetary value for example a day out on, for example, Loch Lomond. Three site quality variables were included in the TCM: noise (perceived noise level on a scale from one to five); crowding (perceived crowding on a scale from one to five) and environmental damage (perceived environmental damage on a scale from one to five). The relationship between the three site quality variables is interesting as only noise is statistically significant. This suggests that noise is the more important site quality variable for visitors to Loch Lomond. More specifically noise has a negative impact of trips and as such, as a site becomes noisier, less people will want to visit. This was confirmed by descriptive statistics: 81% of respondents said high noise levels spoil their recreation enjoyment.

Overall the TCM found that the following variables significantly affect number of trips made to Loch Lomond: travel cost, length of time spent on site, age of respondent, sex of respondent, activity of respondent, mode of transport and perceived noise level. Following on from this, using my TCM, it can be said that a reduction in current noise level to a level of no or very little noise would increase predicted visits to the Loch Lomond area by 4.2%. The TCM indicates that a 'typical' day at Loch Lomond is valued at £20.53 ($37.90), using 95% confidence level as much as £24.72 ($46.38) per person per trip could be gained by the Park Authority (£17.52 to £24.72).

A Contingent Valuation Model (CVM) was created again using the results of the questionnaire survey. The Contingent Valuation method is a technique that asks respondents about their willingness to pay for the option to use environmental resources, or for a quality change to these resources. It is therefore based on people's intentions or stated preference. It is hypothetical. The specific aim of the CVM was to determine the factors that influence a visitor's willingness-to-pay for environmental improvements and estimate this willingness to pay. It is applicable only to environmental damage; we did not apply CVM to either crowding or noise levels. The Willingness-to-pay question in visitor survey is as follows:

"Imagine that the National Park Authority decided to undertake some environmental improvements at this site. These environmental improvements would consist of the protection of ground vegetation and trees, the prevention of shore erosion, and a reduction in the level of water pollution. Imagine that the only way to pay for this programme was to introduce an on-site parking fee. The parking fee options are shown on this card. Thinking about how much extra pleasure you would get from such environmental improvements, would you be willing to pay such a fee to visit the site?

If Yes, which amount on the card shows the MOST would you be willing to pay to visit this site with environmental improvements? If No, why not? "

A payment card was shown to respondents and they were asked to indicate the most they would be willing-to-pay in the form of a car parking fee, in order to fund environmental improvements. Income, Sex and Perception of environmental damage all significantly influence visitor willingness to pay for improved environmental conditions (at $P \geq 0.95$ or better). The most the 'average' visitor would be willing to pay to fund environmental improvements is £1.76 ($3.17) (the minimum WTP is 50p, the maximum is £5). 81.2% of visitors would be willing to pay a car parking fee; 18.8% said they would not be willing to pay. Reasons for this include: "we can't afford to pay every time we come here", "the environment's fine as it is", and "this is part of a National Park, it should be free enjoyment for all". The implication of the CVM is that a parking fee would be best received at those sites where visitors recognise that there already exists some level of environmental damage, such as Sallochy on the east shore. Of all the sites studied it appears that Sallochy has the highest level of environmental damage.

All of these results from the questionnaire survey provide perceptual (social) information on recreation impact. In order to complement these perceptual findings, ecological data is also required. To this end I now discuss the results of my ecological surveys.

Following on from the ecological surveys of the plants around the Loch ecological analysis was carried out using two computer programmes: TWINSPAN and MINITAB. Six different groups of field and shore plant communities were identified by TWINSPAN, at the third level of the divisive classification. A clear geographical division arose between the groups of the field and shoreline community,

primarily between the north and south basin of Loch Lomond. More specifically, a field/shore division was apparent. In other words there was a clear division between types of plant depending on whether they were found in the north or south basin of the Loch or the field or shore zone. For the aquatic communities TWINSPAN identified, again at level three of the divisive classification, five main community types. An invasive/non-invasive binary became apparent, in other words the results suggested that there is a habitat in Loch Lomond not yet invaded by Elodea, an invasive species now increasing in the Loch. Statistical analysis was also carried out in order to determine whether the geographical division for the field and shore communities and the invasive/non-invasive division for the aquatics groups, can be attributed to environmental or recreation factors. For the field and shore communities, the TWINSPAN geographical division (i.e. between north/south basin and field/shore) can be attributed to the following environmental factors: exposure, shade and grazing, along with recreation pressure and visitor damage level. The findings are very similar for the Lomond aquatics. Namely, the environmental factors of exposure, shade and grazing are significant, as is recreation pressure. Visitor damage is not significant for the aquatic communities.

It can therefore be stated that exposure, recreation pressure, visitor damage (for the field/shore communities only), shade and grazing are all important in determining differences between species groups. Crucially then, recreation pressure appears to be an important influence on vegetation communities and hence the 'real' ecology of Loch Lomond.

On the days that the questionnaires were issued (summer 2003) traffic counts were also made at hourly intervals throughout each survey day. The aim of the traffic counts was to establish a physical carrying capacity of each site and to determine whether this is being met or exceeded. At Milarrochy Bay physical carrying capacity was exceeded during one of the six days of the field study. However as a result of good management practice this was not to a detrimental level with regards to environmental conditions. On one of the survey days at Sallochy physical carrying capacity was exceeded. Although perhaps an extreme case, it is clearly cause for environmental and social concern. At Rowardennan physical carrying capacity was met and exceeded on two of the survey days (both Sundays). These peaks in recreation use are clearly cause for management concern – both environmentally and socially. Management restrictions prevent physical capacity from being exceeded at Firkin. Physical carrying capacity was not met nor exceeded on any of the six survey days.

Moving on now to think about the interviews that I undertook as part of my research, from my interviews with management noise is not seen to be an important issue. Crowding is also not seen to be a significant issue. Environmental conditions and resource impacts are often the biggest concern. This is in contrast with visitor perception (results from questionnaires) where noise is seen to be the most significant issue, followed by crowding and lastly environmental damage. Therefore, there appears to be a discrepancy between visitor and manager perception. Overall, the main themes (i.e. main issues for Loch Lomond management teams) are: the need for management frameworks (e.g. carrying capacity); integrated planning and management; information/education; visitor behaviour and conflict (including anti-social behaviour); park management actions; sustainability; resource impacts; environmental damage; and conflict between conservation and recreation.

Thirty-two interviews were also undertaken as part of my Jet-ski debate case study. The use of "jet-skis" in Loch Lomond has proved a popular controversy since establishment of the National Park. It was therefore hoped that a study of the jet-ski debate would bring together the ecological and perceptual dimensions of recreation in a coherent whole. The case study included twelve interviews with sailing club members (face-to-face); five interviews with anglers (phone interviews); two interviews with local businesses involved with jet-skiers and water activities in general (phone interviews) and twelve on-site interviews with jet-skiers (intercept survey at Drumkinnon Bay, May 2004). I also conducted one phone interview with a jet-skier. A number of conclusions can be drawn from the jet-ski case study. The numbers using personal watercraft on Loch Lomond have significantly increased between the 1989 to 2003 period; this growth continues. Personal watercraft has the potential to cause environmental degradation, however this impact is not a serious problem at Loch Lomond at present. Perceived impacts, in particular noise, are a greater problem to the typical Loch Lomond visitor than the actual environmental impact of jet-skis. This has important management implications. There is an extreme division between jet-skiers and non-jet skiers. While the jet-skiers themselves were more concerned with fun and enjoyment (termed here the importance of play), non-jet skiers (sailors and anglers) were affected by noise, safety and environmental impact. Interestingly, conflict appears to be asymmetrical, one-sided, from non-jet skiers. Jet-skiers themselves reported that they were not disturbed by the activities of others.

In order to establish the general level anthropogenic environmental impact around the Loch shore a visitor damage survey was conducted. Visitor damage was defined as evidence of environmental impacts such as litter, dead trees, water pollution, exposed tree roots, broken branches, vegetation trampling, shore erosion and remnants of barbeques.

Table 1. Visitor impact on Grazing pressure

Impact Level	1 no impact	2 low impact	3 moderate impact	4 high impact	5 very high impact	6 artificial/ rock shoreline category for visitor impact only
Visitor Impact: % of total shoreline	39.67	14.57	11.77	8.27	9.13	16.59
Grazing Pressure: % of total shoreline	93.21	0.75	6.04	0	0	N/A

The study encompassed the total shoreline of the Loch, including the shores of all major islands (counted as ten). As shown in Table 1, it was discovered that overall 56% of the loch shoreline has no visible visitor damage (however 17% of this is artificial/rock shoreline, where visitor access is impossible). Ignoring this artificial/rock shoreline, 39.7% of the shoreline has no visible visitor impact. 44% of the shore zone therefore experiences some level of visitor impact, with just over 9% experiencing very high visitor impact levels. In particular pockets of highly damaged, localised areas were seen along the West shore. Much of the northern basin experienced very little or no visitor damage. Grazing pressure was also observed and it was found that the majority of the loch shore zone experiences no grazing pressure. In general terms then, only a limited area of the Loch experiences 'real' environmental damage. It is very spatially specific.

There are a number of policy implications as a consequence of my findings. The TCM estimated a consumer surplus per trip at £20.53 ($37.90) under current conditions. Using the 95% confidence level, as much as £24.72 ($46.38) per person per trip could be gained by the Park Authority. Visitors would be wiling to pay an additional £1.76 ($3.17) per trip to fund environmental improvements. These figures suggest that there is an opportunity for the NPA to generate revenue and help conserve the natural environment, through various environmental and noise reducing policies. In particular management should address the conflict caused by PWC noise. It can do so in four main ways: pricing (charging users to use the loch), zoning watercraft, banning PWC, and education/information. It is argued that pricing and education/information are the best mechanisms by which to deal with this conflict. Currently it is free to enter the National Park and free to park at all the sites under study.

CONCLUSIONS

I created econometric models, which examine the three issues of noise, crowding and environmental damage. A 'typical' day at Loch Lomond is valued at £20.53 ($37.90), with visitors willing to pay an additional £1.76 ($3.17) to fund environmental improvements. As neither the variables of CROWDING nor ENVIRONMENTAL DAMAGE are significant in the TCM the implication is that neither crowding nor environmental damage need be a priority for the LLTNPA. However, scientific perception of environmental damage may differ from visitor perception, meaning that action is justified. What is more, my CVM survey shows that people are willing to pay for measures that reduce environmental damage, once this has been explained to them. With regard to crowding, my TCM model may miss out the impacts on utility per trip of increases in crowding at particularly busy occasions. Loch Lomond does not have the crowding levels as experienced at the Lake District National Park in the north of England for example, thus on only a few occasions can the sites be termed physically crowded. NOISE pollution is the most important site quality variable, thus for the 'typical' Loch Lomond visitor, high noise levels have the greatest impact on their recreation enjoyment. This is linked into the jet-ski debate.

Through the study of the jet-ski debate, it was found that conflict exists between jet-skiers and other recreationalists. It is important to note that this conflict is one-sided, from the perspective of the non-jet skier.

My ecological surveys indicate that recreation pressure significantly affects the presence/absence of plant communities. Therefore recreation does affect the real ecology of the area, but as the visitor damage survey illustrates this is to a limited spatial (and indeed temporal) extent.

Overall my research is unique as it brings together the ecological and social aspects of outdoor recreation in the Loch Lomond area. It provides information on the social and ecological impacts of recreation and should help to inform the Loch Lomond and Trossachs National Park Authority on future research needs. An overall conclusion to the project is still to be reached, however it appears that a sustainable approach to recreation management, one that encompasses the perceptual/social and ecological dimensions of recreation, is the only way of maintaining the beauty and enjoyment of Loch Lomond for future generations.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support of the Economic and Social Research Council (ESRC) and Natural Environmental Research Council (NERC) for jointly funding this study (ESRC-NERC studentship PTA 036 2002 00002). I would also like to thank my three supervisors, Dr Gordon Dickinson (Department of Geographical and Earth Sciences, University of Glasgow), Dr Kevin Murphy (Division of Environmental and Evolutionary Biology, University of Glasgow) and Prof. Nick Hanley (Department of Economics, University of Stirling) for their help and assistance with this project. Without such support this research would not have been possible.

REFERENCES

Bannan, M. (1999). *The Effects of Powerboat Emissions on the Water Quality of Loch Lomond*. Department of Environmental and Evolutionary Biology. University of Glasgow. Unpublished PhD thesis.

Dickinson, G. (1994). "Vegetation and land use in the Loch Lomond catchment." *Hydrobiologia*. 290, 53-61.

Dickinson, G. (1996). Environmental Degradation in the Countryside: Loch Lomond, Scotland. *Sustainable Tourism? European Experiences*. In G. K. Priestley, J. A. Edwards and H. Coccossis. (Eds.) Oxon, CAB International.

Hanley, N., Shaw, D. W. and Wright, R.E.. Eds. (2003). *The New Economics of Outdoor Recreation*. Cheltenham, Edward Elgar.

Hansom, J. D. and McGlashan, D.J. (2000). *Impacts of Bank Protection on Loch Lomond*. Glasgow, Scottish Natural Heritage.

Murphy, K., Beveridge, M. C. M. and Tippett, R. (1994). *The Ecology of Loch Lomond*. London, Kluwer Academic Publishers.

Tivy, J. (1980). *The Effect of Recreation of Freshwater Lochs and Reservoirs in Scotland*. Glasgow, Countryside Commission for Scotland.

The Glasgow Naturalist Volume 24 Part 3 Pages 23-28 (2005).

THE AQUATIC FAUNA OF LOCH LOMOND AND THE TROSSACHS: WHAT HAVE WE GOT; WHY IS IT IMPORTANT; HOW DO WE LOOK AFTER ITS FUTURE

Peter S. Maitland[1] and Colin E. Adams[2]

[1]Fish Conservation Centre, Gladshot, Haddington, EH41 4NR

[2]University Field Station, Institute of Biomedical & Life Sciences, University of Glasgow, Loch Lomondside, G63 0AW

ABSTRACT

Conservation of the natural heritage is supposed to be a top priority of the Loch Lomond and the Trossachs National Park Authority. Yet sustainable management of wildlife within the Park will only be possible if adequate scientific data on the temporal and spatial status of species and habitats are available. It is therefore important to have reliable information on the present status of aquatic wildlife and to have monitoring programmes which will be sufficient to detect significant changes in the future. However, resource implications mean that only limited long-term monitoring will be possible and suitable strategies must be devised now. Possible species for monitoring include flagship, keystone and indicator organisms as well as certain alien species and important habitats.

INTRODUCTION

If we are to manage the wildlife and habitats of Loch Lomond and the Trossachs we must have an idea of what species and habitats are there and if, through time, these are changing – and whether any changes are desirable or undesirable. If the latter is true, we additionally need to know if there is anything that we can do about it, and perhaps reverse undesirable trends? This paper broadly examines what is known about the aquatic fauna of Loch Lomond and the Trossachs and seeks to identify important species which it is realistic to monitor in order that we may be better able to manage the wildlife resources of the area.

Because of the potential commitment of resources for indefinite periods it is important to consider the cost implications of any monitoring programme which is proposed. Thus the debate must review the pros and cons of any potential project and view widely the options for minimising resource requirements whilst still producing the information essential for future management of species and habitats.

THE AQUATIC FAUNA

Invertebrates

The number of aquatic invertebrates established in the Loch Lomond and the Trossachs area is unknown and almost impossible to establish if microscopic species are included. The fact that several of the less common aquatic habitats have never been examined properly (Maitland 1999) adds to the difficulty of completely describing the current biodiversity. For Scotland as a whole, Usher (1997) estimated that there were some 19,200 terrestrial and freshwater invertebrates, excluding microsopic forms (Viruses, Bacteria, Protozoa etc.). Only a small proportion of these invertebrates are freshwater species and Maitland (1977) listed the known list of aquatic macroinvertebrates in the British Isles as including some 3,800 species – probably at least 50% of these occur in Scotland.

In terms of species lists for known waters within Loch Lomond and the Trossachs area, more accurate information is available. For example, Maitland (1966) recorded 73 macroinvertebrate species in the main stem of the River Endrick (272 for the whole river system) and a similar number (70) was recorded by Doughty & Maitland (1994). In their study of streams in two areas west of Aberfoyle, Harriman & Morrison (1982) recorded 43 different taxa. In Loch Lomond itself, a total of 103 species has been recorded - from the littoral (47 species), profundal (45) and pelagic (11) zones by Smith et al. (1981), Slack (1965) and Maitland *et al.* (1981) respectively. In all cases these are minimum numbers, for some groups were not examined in detail as several diverse groups have only been poorly recorded (e.g. Rotifera, Hydracarina, Diptera) and others not studied at all (Nematoda, Microturbellaria, Tardigrada) in this catchment. Of the groups that have been well documented for the Loch Lomond catchment, this area has records of 331 aquatic species (Adams *et al.* 1990)

Vertebrates

The number of vertebrates in the Loch Lomond and the Trossachs area is much better known than that of invertebrates, as fish, amphibians and birds have been much more intensively studied. Only fish are considered here and elsewhere in this paper. The total number of freshwater fish species known to occur in Scotland is 42 (Adams & Maitland 2001) and of these 35 have been recorded from Loch Lomond and the Trossachs area (Maitland 2002). However, of these 35 species, only 22 are considered to be native (Adams & Maitland 2001), the remainder are alien species introduced mostly in the recent past.

IMPORTANT SPECIES

The decision as to which species are 'important' is a subjective one and can depend on the context involved. For example, rare native species are certainly important and worthy of study and conservation, but so too may be quite common species which have an important, even crucial, ecological role within a given habitat. Species of economic significance must also be deemed important.

Natives

Rare invertebrate species found in Loch Lomond and the Trossachs area include the Lomond worm, *Arcteonais lomondi*, the subterranean crustacean *Bathynella natans*, the mollusc *Bithynia leachii*, and three dragonflies: the Downy Emerald *Cordulia aenea*, Beautiful Demoiselle *Calopteryx virgo* and Northern Emerald *Somatochlora arctica*. Common species of note because of their role in the functioning of aquatic ecosystems, are the worm *Eiseniella*

tetraedra, the crustaceans *Diaptomus gracilis*, *Gammarus pulex* and *Asellus aquaticus*, the mollusc *Lymnaea peregra*, and the water bug *Sigara dorsalis*. No aquatic invertebrates are of direct economic importance, though biting midges (Ceratopogonidae), some of which are aquatic and which are abundant in the area, might be regarded by some as such.

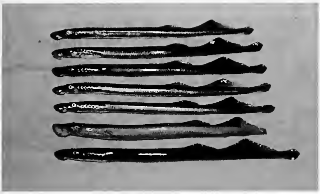


Fig. 1. Loch Lomond river lampreys

Rare freshwater fish within the Loch Lomond and the Trossachs area include the unique form of River Lamprey *Lampetra fluviatilis* (Fig. 1) in Loch Lomond and the River Endrick, the Powan *Coregonus lavaretus* of Lochs Lomond and Eck and the polymorphic Arctic Charr *Salvelinus alpinus* of the Trossachs lochs. Common fish species which are of ecological importance, because of the key role they play in the functioning of aquatic ecosystems in Loch Lomond and the Trossachs area, include Roach *Rutilus rutilus*, Minnow *Phoxinus phoxinus*, Atlantic Salmon *Salmo salar* (particularly the juvenile stage), Brown Trout *Salmo trutta*, Pike *Esox lucius*, Eels *Anguilla anguilla* and Perch *Perca fluviatilis*. Atlantic Salmon and Brown Trout (and to a lesser extent Eels) are of considerable economic importance as they support significant fisheries in the area which make a notable contribution to the local economy (Radford & Gibson 2004). Additionally some fish species found in the area are of importance because of concern about national trends in populations, these include: Eels, regarded as below sustainable exploitation levels internationally (ICES 1998); Atlantic Salmon (in Annex IIa and Va in the Habitats and Species Directive) and the migratory form of Brown Trout (the Sea Trout) which has shown significant declines in some rivers in recent decades (Hay & McKibben 2005).

Aliens

Many alien species are now established in the Loch Lomond and Trossachs area and some have caused significant ecological change. They include invertebrates such as *Potamopyrgus antipodarum* and *Crangonyx pseudogracilis* (Maitland & Adams 2001) and at least 13 alien fish species such as Crucian Carp *Carassius carassius*, Carp *Cyprinus carpio*, Brook Charr *Salvelinus fontinalis*, and Ruffe *Gymnocephalus cernuus* (Adams & Maitland 2001). One important function of monitoring should be to record the first findings of any such species, so that immediate efforts can be made to eliminate them, but also to monitor populations so that their impact on native species and communities can be assessed.

WHAT TO MONITOR?

Flagship species

Flagship species can be defined as a species that can evoke a strong public reaction and through this can promote conservation issues.

Because of their small size and often obscure habits, invertebrates are less easy than vertebrates to promote in this way but there are several important candidates.

Arcteonais lomondi – The first discovery ever of this species was in Loch Lomond, and is reflected in its nomenclature. It has the potential to capture the imagination because of this local historical significance, thus potentially making it a flagship species. Its abyssal habitat is also intriguing. However as with many other invertebrates, this animal does not lend itself to attractive promotional images.

Fig. 2. Freshwater pearl mussel

Freshwater Pearl Mussel *Margaritifera margaritifera* (Fig. 2) – this fascinating but declining large mollusc must surely qualify as a flagship species. Its ability to live for over a century as a calcium demanding bivalve which lives in calcium poor waters, together with its historic role as a producer of freshwater pearls for the Scottish Crown and other regalia, have given it a particular prominence in recent years.

Pisidium conventus – this small bivalve mollusc occurs on the bottom only in the deepest water of Loch Lomond – the 'Tarbet Deep' at 190 m (Hunter & Slack 1958). It has considerable significance here as it considered a good example of an Arctic relict species, found mainly in the profundal areas of deep lochs further north in Scotland and Scandinavia.

Powan (Fig. 3) – This fish - a suitable candidate because its rarity in Scotland and the UK generally - defines in part, some of the special nature of the Loch Lomond and the Trossachs area. A suitable project in Lochs Lomond and Eck could allow the fish community, as a whole, to be covered by a monitoring programme which concentrates on Powan but also samples many other species and could be devised to identify major change in native fish populations and to detect any new arrivals.

Arctic Charr (Fig. 4) – This should be considered as a flagship species, partly because its beauty has an impact amongst those members of the public who do not immediately identify with fish conservation, and partly because the evolutionary story associated with this species has much to reveal to specialists and non-specialists about contemporary evolution.

Fig. 3. Powan

Fig. 4. Arctic charr

Salmon – This is certainly a potential flagship species used successfully as such elsewhere (e.g. in the Thames restoration scheme: Gough 1987). Its complex life cycle, existing public identity as requiring high water quality and economic value make this species ideal for promotion as a potential flagship species. Historically it is closely associated with the City of Glasgow and its Coat of Arms.

Possibly less suitable candidates include:
Eel – The intriguing life cycle of this amazing animal, its ubiquity in freshwater systems and its vulnerability make this a good potential flagship species. However the public persona of the Eel mitigates against it to some extent.

River lamprey – The unusual life cycle of this species in the River Endrick partly defines the unique nature of the Loch Lomond and the Trossachs area and as such is one of the key "stories" that visitors to the area should have the opportunity to learn. Thus this species is a potentially good flagship species for the area, though its feeding habits and lack of photogenicity may work against it.

Keystone species
Keystone species are species which are disproportionately important to the maintenance of community integrity and following whose extinction major ecological changes would ensue.

Invertebrates – Within Loch Lomond, the major water within the National Park (Maitland *et a*l. 2001), and other large lochs, invertebrates need to be considered within each of the three main communities – littoral, profundal and pelagic. Any programme on invertebrates must build upon the standard methodologies and extensive sampling programmes currently operated by the Scottish Environmental Protection Agency (SEPA) to get the best value for effort. For riverine invertebrate communities in particular there are internationally recognised techniques and protocols (e.g. BMWP and RIVPACS) for estimating change which can be incorporated in monitoring.

Littoral – *Gammarus pulex* is a strong contender here, not least because it may be being replaced at the moment by the invasive species *Crangonyx pseudogracilis* (Maitland & Adams 2001). Other important invertebrates include the mayfly *Caenis moesta* – a ubiquitous native of significant importance in aquatic food chains. The littoral zones are highly important to the functioning of lochs but are also very vulnerable to anthropogenic effects. These animals play a key role in their healthy functioning and thus could identify any change.

Profundal – As well as oligochaete worms and sphaeriid bivalves, chironomid midge larvae are important invertebrates in the deep water muds of Loch Lomond. Most characteristic among these are members of the genus *Tanytarsus*, typical of oligotrophic lakes (Slack 1965). Changes in this group of invertebrates would significantly affect the way in which deep water processes in lochs operate.

Pelagic - *Diaptomus gracilis* is the commonest member of the zooplankton in Loch Lomond and has been shown to form at least 40% of the pelagic community (Chapman 1969). Other important zooplankton are *Bosmina coregoni* and *Daphnia hyalina*. These species are principal drivers of food chains in open water in lochs. Their short generation time and the speed at which they respond to environmental change make them potentially sensitive markers of environmental pressures.

Riverine invertebrates – keystone species from rivers and streams within the Loch Lomond and Trossachs area include several species of stoneflies (Plecoptera) and mayflies (Ephemeroptera), two abundant and ubiquitous groups which are known to be sensitive to change in riverine environments.

As with fish communities, invertebrate sampling could concentrate on one (or a few) species within each community but keeping a record (with minimal effort) of other species/taxa to detect change. The value of archive samples for future research projects should also be given serious consideration.

Pike – At the top of the aquatic food chain and with a very wide distribution in Loch Lomond and the Trossachs, pike has the potential to act as a keystone species. Its position in the food chain means that change in aspects of the aquatic ecosystem lower down the trophic cascade is very likely to be manifest in changes in this species. Thus pike can act as an integrator of ecosystem change providing a valuable indicator mechanism - including its tendency to act as a bioaccumulator of anthropogenic toxins such as dieldrin and other pesticides.

Brown Trout – This is the most widespread fish in the area, and often the only species in upland burns and lochs. In these it is the major aquatic predator and with its extinction, as has happened with the acidification of a number of waters, major changes take place in the invertebrate communities (Henriksen & Oscarson 1978, 1981, Lyle & East 1989).

Indicator species

The use of indicator species is well known in ecology and especially important in pollution biology. Once the ecological tolerances of an organism have been defined it is possible to use its presence in a habitat to assume that conditions there lie within these tolerance levels. Hellawell (1986) has noted that ideal environmental indicator species are readily identified, may be sampled easily, have a cosmopolitan distribution, are associated with abundant autecological data, are easily cultured, and have a low genetic and niche variability.

The measure of the impact of global warming is a special issue which is worthy of its own mini programme since there may be general changes resulting, which are driving everything else. It is also feasible in this context to make some predictions and then test them using monitoring records. Several invertebrate species might be good indicators here. The mayfly *Ameletus inopinatus* occurs in the Lomond catchment only at high altitudes (e.g. near the source of the River Endrick). Further south it occurs only at even higher sites, but in the north of Scotland is found down to sea level. Predictably, it will disappear from the Lomond catchment as the climate warms. Another mayfly, *Ephemerella ignita*, at present has only one generation each year in the Loch Lomond area and is only found as larvae during the summer but further south in Britain it is present all the year round, whilst on parts of mainland Europe there may be two generations. Predictably, in the Loch Lomond area, with increasing annual temperatures, the larvae would be present all year round and the number of generations would increase. Monitoring of the distribution of the former and the life cycle of the latter, would provide an index of climate change.

Of course, there are other species which could be considered as useful indicators. Also, such changes may already be happening for no-one has looked at the mayfly species mentioned above for some time.

Fig. 5 Medicinal leech

Restoring biodiversity

Several species are declining in the area and others have become extinct. A notable example of the latter is the Medicinal Leech *Hirudo medicinalis* (Fig 5) which formerly occurred in 'a pool near the Loch of Menteith (Dalyell 1853) – possibly Loch Macanrie (Maitland 1996) – and in 'certain ponds belonging to John Burn Murdoch Esq. of Gartincaber' whose estate lay near Thornhill. In view of the extreme rarity of this species elsewhere in Scotland (only two sites are known) a programme to restore this important species is overdue.

RARE HABITATS

Although a number of the larger rivers and lochs in the area have been studied in the past, very little attention has been paid to less usual, but sometimes common, ecosystems – such as ephemeral ponds and streams, subterranean and interstitial waters, high altitude streams and bog pools, moss cascades and other fascinating habitats (Maitland 1999). Research on these aquatic systems is likely to reveal much of interest, including the possibility of new species in otherwise well known geographic areas. Although many of these habitats are under threat, few have protection and we may well be losing interesting habitats and species without ever knowing anything about them.

BENEFITS AND LIMITATIONS OF MONITORING

Benefits

Small scale, incremental, environmental change is notoriously difficult to demonstrate adequately. Natural variation in the size of populations of plants and animals is frequently large, creating 'noise' that masks underlying (perhaps anthropogenic) trends, that may be of importance. Although highly frustrating for managers of ecosystems, who usually need to make decisions on a much shorter time-scale, it is difficult to identify insidious fine-scale and cumulative incremental ecosystem change without long-term monitoring data. Without these types of data, sound evidence-based ecosystem management decisions to prevent or mitigate against such change is impossible.

We should also attempt to maximise relevant information available from samples if this helps to detect potential stress and serve as a warning for possible future decline of a population. An example of this in relation to fish samples is the analysis of change in fish size, growth rate, condition or parasite load which might be an indirect indicator of more significant undesirable change in the fish community.

Costs

Monitoring anything in perpetuity has a number of resource commitments and should not be undertaken lightly. The costs of field work and any subsequent laboratory or data analyses may be considerable over the long term and a traditional area for those in accounting to terminate when financial resources are limited.

Destructive sampling

Certain types of sampling are destructive and should be avoided if possible – especially if the size of the population is unknown or is believed to be threatened. When there is doubt, the Precautionary Principle should apply and only non-destructive methods employed.

Change of policy
There are many examples of where a change of policy or change of personnel has meant the abandonment of a previous monitoring programme. Any programme which is believed to be of importance should be given periodic guarantees of time-limited continuance, with a review of the project at the end of each period.

Opportunism
In view of the, often high, costs of monitoring and the difficulties of carrying out appropriate sampling any serendipitous opportunities to sample important species or events should be undertaken.

A good example of opportunistic sampling was the coincidence of the discovery of Ruffe in Loch Lomond (Maitland et al. 1983) with the decision to sample fish on the screens of a water supply pumping station at Ross Priory. For relatively little effort it has been possible to monitor several species captured by the intake there, and in particular follow the population explosion of alien Ruffe during their early decades in Loch Lomond (Adams & Maitland 1998).

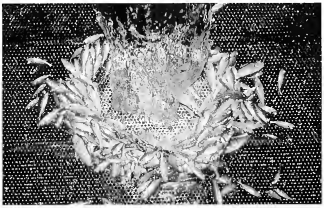


Fig. 6. Fishscreen at Ross Priory

There are many other opportunities to obtain valuable monitoring data with minimal effort, given appropriate circumstances. For example, if Powan are to be monitored regularly at Loch Lomond then the regular recording of scars and wounds on these fish caused by feeding River Lampreys (Maitland 1980) could, for relatively little extra effort, give a valuable indirect method of monitoring adult lampreys in the loch.

One opportunity which has arisen recently is the possibility of monitoring certain groups of adult insects which are collected in the highly efficient midge traps increasingly being installed in the vicinity of hotels and caravan sites in the Loch Lomond and Trossachs area.

MANAGEMENT

A range of organisations have statutory obligations or at least responsibilities to manage species or habitats with the Loch Lomond and Trossachs area. Since it is difficult to manage on a scientific basis without information from monitoring then there is mostly an implied obligation to monitor. Some of the most important of these responsibilities are indicated in Table 1.

CONCLUSIONS

Without reliable scientific data, the Loch Lomond and the Trossachs national Park Authority will not be able to carry out its responsibility to manage the wild life resources of the Loch Lomond and Trossachs area on a sustainable basis. Such data may only be obtained through the implementation of well designed programmes which monitor selected organisms, communities and habitats in the area. However, in order to minimise the implied regular costs of such progammes, each must (a) be carefully designed, and (b) maximise the input from all those concerned, including statutory bodies, NGOs and voluntary bodies such as the Glasgow Natural History Society.

Table 1. Organisations with responsibilities for monitoring and managing aquatic wildlife in the Loch Lomond and Trossachs area.

Organisation	Responsibility	Requirement for aquatic species/habitats
Fishery Trusts	Fish within their areas	Regular assessment of freshwater fish populations
LLTNP	Wildlife within the Park	Co-ordination and archiving of monitoring data
SEPA	Aquatic pollution indicators	e.g. aquatic benthos to detect pollution
SNH	Wildlife within protected areas	e.g. lampreys and salmon in River Endrick SAC

ACKNOWLEDGEMENTS

We are grateful to the Glasgow Natural History Society for the opportunity to outline the suggestions for monitoring included in this paper.

REFERENCES

Adams, C.E., Brown, D.W., Little, S.S. & Tippett, R. (1990). A check-list of the freshwater invertebrate fauna of the Loch Lomond catchment. *Glasgow Naturalist* 21, 537-554.

Adams, C.E. & Maitland, P.S. (1998). The ruffe population of Loch Lomond, Scotland: its introduction, population expansion and interaction with native species. *Journal of Great Lakes Research* 24, 249-262.

Adams, C.E. & Maitland, P.S. (2001). Invasion and establishment of freshwater fish populations in Scotland – the experience of the past and lessons for the future. *Glasgow Naturalist* 23, 35-43.

Chapman, M.A. (1968). The bionomics of *Diaptomus gracilis* Sars (Copepoda: Calanoida) in Loch Lomond, Scotland. *Journal of Animal Ecology* 38, 257-283.

Dalyell, J.G. (1853). *The powers of the Creator as displayed in the Creation.* Van Voorst, London.

Doughty, C.R. & Maitland, P.S. (1994). The ecology of the River Endrick: present status and changes since 1960. *Hydrobiologia* 290, 139-151.

Gough, P.J. (1987). Thames salmon rehabilitation – the next steps. *Atlantic Salmon Trust Progress Report,* December 1987, 23-24.

Harriman, R. & Morrison, B.R.S. (1982). Ecology of streams draining forested and non-forested catchments in an area of central Scotland subject to acid precipitation. *Hydrobiologia* 88, 251-263.

Hay, D. & McKibben, M. (2005). Shieldaig Sea Trout Project. *Atlantic Salmon Trust Winter Journal* 2004/5: 10-13.

Hellawell, J.M. (1986). *Biological indicators of freshwater pollution and environmental management.* Elsevier, London.

Henrikson, L. & Oscarson, H.G. (1978). Fish predation limiting abundance and distribution of *Glaenocorisa propinqua. Oikos* 31, 102-105.

Henrikson, L. & Oscarson, H.G. (1981). Corixids (Hemiptera-Heteroptera) the new top predators in acidified lakes. *Verhandlung der Internationalen Vereinigung fur theoretische und angewandte Limnologie* 21, 1616-1620.

Hunter, W.R. & Slack, H.D. (1958). *Pisidium conventus* Clessin in Loch Lomond. *Journal of Conchology* 24, 245-247.

ICES. (1998). *European Eel.* Extract of the report of the Advisory Committee on Fishery Management. 14 pp.

Lyle, A.A. & East, K. (1989). Echo location of corixids in deep water in an acid loch. *Archiv fur Hydrobiologie* 115, 161-170.

Maitland, P.S. (1966). *The fauna of the River Endrick.* Blackie, Glasgow.

Maitland, P.S. (1977). *A coded checklist of animals occurring in fresh water in the British Isles.* Institute of Terrestrial Ecology, Edinburgh.

Maitland, P.S. (1980). Scarring of Whitefish (*Coregonus lavaretus*) by European River Lamprey (*Lampetra fluviatilis*) in Loch Lomond, Scotland. *Canadian Journal of Fisheries and Aquatic Sciences* 37, 1981-1988.

Maitland, P.S. (1996). Recovery of the Medicinal Leech *Hirudo medicinalis* in Scotland. Phase 1. *Report to Scottish Natural Heritage, Edinburgh.*

Maitland, P.S. (1999). New horizons – new species? The invertebrate fauna of unexplored aquatic habitats in Scotland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 9, 529-534.

Maitland, P.S. (2002). Freshwater fish of the Loch Lomond and the Trossachs National Park. *Forth Naturalist and Historian* 25, 53-64.

Maitland, P.S. & Adams (2001). Introduced freshwater invertebrates in Scotland: enhanced biodiversity or a threat to native species. *Glasgow Naturalist* 23: 26-34.

Maitland, P.S., Adams, C.E. & Mitchell, J. (2001). The natural heritage of Loch Lomond: Its importance in a national and international context. *Scottish Geographical Journal* 116, 181-196.

Maitland, P.S., East, K. & Morris, K.H. (1983). Ruffe, *Gymnocephalus cernua*, new to Scotland, in Loch Lomond. *Scottish Naturalist* 1983, 7-9.

Maitland, P.S., Smith, B.D. & Dennis, G.M. (1981). The ecology of Scotland's largest lochs: Lomond, Awe, Ness, Morar and Sheil. 6. The crustacean zooplankton. *Monographiae Biologicae* 44, 135-154

Radford, A. & Gibson, H. (2004). *The economic impact of game and coarse angling in Scotland.* Scottish Executive, Edinburgh.

Slack, H.D. (1965). The profundal fauna of Loch Lomond. *Proceedings of the Royal Society of Edinburgh* 69, 272-297.

Smith, B.D., Maitland, P.S., Young, M.R. & Carr, M.J. (1981). The ecology of Scotland's largest lochs: Lomond, Awe, Ness, Morar and Sheil. 7. The littoral zoobenthos. *Monographiae Biologicae* 44, 155-203.

Usher, M.B. (1997). *Scotland's biodiversity: an overview.* Pages 5-20 in: Fleming, L.V., Newton, A.C., Vickery, J.A. & Usher, M.B. (Eds.) *Biodiversity in Scotland: status, trends and initiatives.* The Stationery Office, Edinburgh.

The Glasgow Naturalist Volume 24 Part 3 Pages 29-35 (2005).

ECOLOGY AND CONSERVATION OF OTTERS *(LUTRA LUTRA)* IN LOCH LOMOND AND THE TROSSACHS NATIONAL PARK

Dominic J. McCafferty

Department of Adult & Continuing Education, University of Glasgow, St Andrews Building, 11 Eldon Street, Glasgow G3 6NH.

ABSTRACT

Loch Lomond and The Trossachs National Park contains a diverse range of freshwaters and has adjacent coastal habitats suitable for otters (*Lutra lutra*) and their prey. Otters are found throughout the park and previous surveys suggest that they have recently reoccupied areas of their former range. Otters typically have home ranges containing at least 10 – 20 km of river, stream or loch. However due to variation in population density in different habitats it is not yet possible to estimate total population size. Otters feed on most species of fish present within the park and species taken is dependent on availability within different rivers and lochs. Eels are one of the principal prey due to their high energy content and amphibians are seasonally important. Specific requirements in freshwaters are for reed beds and islands for resting and breeding. The greatest threat to otters in the park at the present time is expected to be road mortality. Given the importance of agriculture within the park any potential effects of pollution on otters and their prey will be from pesticide use rather than from PCBs that are associated with industry. Disturbance to otters from anglers, walkers and dogs is thought to influence behaviour of animals only for short periods of time, however longer term effects of disturbance on breeding females and young is less well understood. Improvements in the status of otters within the park could be achieved by prevention of road mortalities, protection of breeding sites, habitat management for reed beds and riparian vegetation and long term monitoring of water quality and prey biomass.

INTRODUCTION

Scotland has remained a stronghold of the Eurasian otter (*Lutra lutra*) during its recent population decline in England and Wales (Chanin 2003). Although European otter populations are now recovering and expanding into previous parts of their range, the otter is a priority species in the UK biodiversity action plan (Joint Nature Conservancy Council 1994). The otter is listed on Appendix 1 of CITES, Appendix II of the Bern Convention and Annexes II and IV of the Habitats Directive. It is protected under Schedule 5 of the Wildlife and Countryside Act 1981 and Schedule 2 of the Conservation (Natural Habitats) Regulations 1994 (Regulation 38). The European sub-species is also listed as globally threatened on the IUCN / WCMC Red Data List.

There have been four national surveys examining the distribution of otters in Scotland in 1977-9, 1984-5, 1991-4 (Green & Green 1997) and 2003-4 (completed but unpublished) and several detailed studies on their biology and behaviour in the Shetlands (Kruuk 1995), Mull (Watt 1993), Isle of Skye (Yoxon 1999), Lochaber (Kruuk & Hewson 1978) and Argyll (McCluskie 1998). Otters occupying freshwater habitats have been examined in detail in NE Scotland on the catchments of the rivers Dee and Don (reviewed in Kruuk *et al.* 1998) and on the River Earn catchment in Perthshire (Green *et al.* 1984).

Loch Lomond and The Trossachs National Park contains a wide range of still and flowing fresh water systems that provide suitable habitat for otters and their prey. Still waters range from large deep lochs such as Loch Lomond (7100 ha) to numerous small hill lochs and artificial ponds. River systems are typically well oxygenated, low nutrient waters that predominantly contain fish from the salmonid family. There are also a number of fish populations within the park that are important prey of otters including eels (*Anguilla anguilla*) and cyprinids (Chanin 2003, LL&TNP Fish and Fisheries Forum 2004). Otters living in the park are not confined to freshwater systems as the boundary runs along 65 km (approximately 20 % of the 350 km park boundary) of coastline of three sheltered sea lochs.

The aim of this study was to examine the suitability of Loch Lomond and The Trossachs National Park for otters by providing:

1. a review of how otters use freshwater and marine habitats in Scotland,
2. a summary of available information on otters in the Loch Lomond and The Trossachs area
3. an outline of conservation priorities for otters in the national park

HABITAT USE BY OTTERS

Otters may occupy both freshwater and marine habitats within their home range and there are ecological differences in the way otters use these habitats (Table 1).

	Freshwater	Marine coastal
Main activity pattern	nocturnal (dawn & dusk)	diurnal
Foraging areas	still and flowing waters marshland	Within 100 m coast
Mean dive depth and duration	< 2 m and <15 s (lochs)	< 2 m and < 20 s
Specific habitat preferences	reed beds and islands	freshwater pools or streams
Holt and rest sites	above ground (couches) below ground	underground

Table 1. Differences in habitat use by freshwater and marine coastal otters. Summarised from Kruuk (1995, 1998).

Green *et al.* (1984) studied two females that occupied between 16 and 22 km while a male occupied 39 km of rivers, streams and lochs. In the river Dee and Don catchments there was a median estimate of one otter per 15 km of stream (Kruuk & Hewson 1978). In Shetland females have been recorded living in group ranges of 5 – 14 km of coast, males had larger ranges of up to 19 km overlapping with several group areas (Kruuk 1995). In this area there were on average 0.5 – 0.7 otters per km of coast. Expressed on an area basis these studies suggest that otters are found at densities in the order of one otter per 10 ha of water (Kruuk 1995). However this figure should be used with caution as estimates range between 2 and 50 ha.

Otters forage in a wide range of freshwaters including lochs, artificial lakes, marshland, rivers and particularly important are narrow streams with high prey biomass (Kruuk *et al.* 1998). Specific habitat requirements include reed beds and islands on lochs and rivers. These are required for resting and breeding sites but there appears to be no obvious correlation between otter distribution and vegetation cover (Kruuk *et al.* 1998, Thom *et al.* 1998). A variety of secluded sites below and above ground are used as holts, natal holts and couches for resting (Kruuk *et al.* 1998).

Otters occupy a range of coastal habitats in Scotland including both sheltered and exposed shorelines. The distribution of coastal dwelling otters is strongly associated with the occurrence of freshwater pools or streams, as this is an essential requirement for maintenance of healthy fur for thermoregulation. Holt sites are often underground below rocks or within peat banks (Kruuk 1995). In coastal areas otters are generally more active during daylight hours, while in freshwater most activity occurs at night, especially at dawn and dusk. This difference in behaviour is related to prey availability. Many marine prey are less active during the day, while in freshwater, some prey are least active at night. Foraging patterns of otters are also influenced by the tide, with otters in Shetland foraging least during high tide (Kruuk 1995). In coastal areas otters feed within 100 m of the coast, diving to depths not exceeding 10 m, with most dives within 2 m of the surface and lasting less than 20 seconds. In freshwater lochs otters dive to similar depths but for slightly shorter durations, averaging around 13 seconds and often coming ashore with prey (Conroy & Jenkins 1986). In both freshwater lochs and in the sea, otters concentrate their fishing effort in patches, diving and searching in a relatively small area of water before moving to new areas (Kruuk 1995). Otters forage in the margins of rivers and streams, avoiding the strongest current, and exploit shallow riffles when feeding on large salmonids (Carss *et al.* 1990). Marshland habitat is frequently used by otters, especially during spring when feeding on amphibians (Weber 1990).

Radio-tracking studies indicate that there is a difference between the use of freshwaters by males and females. Green *et al.* (1984) tracked two female and one male otter over several months. Within the home range of one female there was running water, still water and marshland but this animal spent 73 % of the time in one productive artificial lake. The second female had both running water and marshland within its home range and spent 72 % in the latter. In comparison the male occupied all three habitat types but spent 60 % of the time on the main river. In Deeside, adult males spent 62 % of their time on the main river while females and young males spent 87 % of the time on lochs and small tributaries (Kruuk *et al.* 1998). Habitat separation between male and female otters has also been recorded in coastal areas at certain times of the year (Kruuk 1995).

ECOLOGY OF OTTERS IN THE LOCH LOMOND AND THE TROSSACHS AREA

Habitat and distribution

Much of the information on otters living within the park is based on previous sign surveys (Green & Green 1997, McCafferty 2005) or anecdotal sightings of animals from members of the public, rangers and gamekeepers. The 1991-4 national survey recorded signs of otters in most freshwater systems within the geographical area of park and in the sea lochs bordering the park (Fig. 1). Nevertheless, future surveys of coastal areas are required to establish the importance of marine habitats for otters living within the park. The only known detailed study of otters undertaken within the geographical area of the park was by Green *et al* (1984). This study highlighted the importance of all freshwater habitats for otters within the upper Earn catchment.

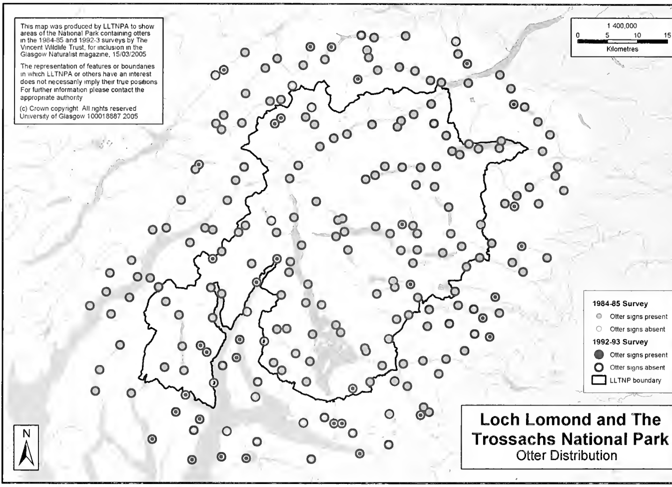


Fig 1. Distribution of otters within Loch Lomond and The Trossachs National Park as recorded by the Vincent Wildlife Trust's otter surveys of Scotland in the 1980s and 1990s.

Prey and diet

The diet of otters in the region of the park is similar to other freshwater areas of Britain, with fish dominating the diet and amphibians being particularly common during late winter and spring (Cameron 1981, Green *et al*, 1984, McCafferty, 2005). In the upper Earn catchment otters have been recorded feeding on *Salmo* spp., eels, cyprinids, perch (*Perca fluviatilis*), sticklebacks (*Gasterosteus aculeatus)*, amphibians as well as birds and mammals (Green *et al.* 1984). In Loch Lomond spraints also included ruffe (*Gymnocephalus cernuus)*, powan (*Coregonus lavaretus)*, northern pike (*Esox lucius)* and lampreys *(Lampetra* spp.) and changes in the diet were associated with the migration and spawning habits of a number of species (McCafferty, 2005). An analysis based on the recovery of otoliths (this study) indicated a similar pattern to that previously found. A total of 268 otoliths (59 %) were recovered from 453 spraints collected from Jan - Dec 2002 (see (McCafferty, 2005 for method of recovery). The frequency of occurrence was ruffe (52 %), cyprinids (51 %), eel (26 %), *Salmo* spp. (14 %), powan (4 %), pike (1.5 %) and perch (1.5 %). Both methods of diet analysis show that the most frequently occurring prey in spraints was the ruffe but there were small differences in the rank abundance of cyprinids and eel (Fig. 2).

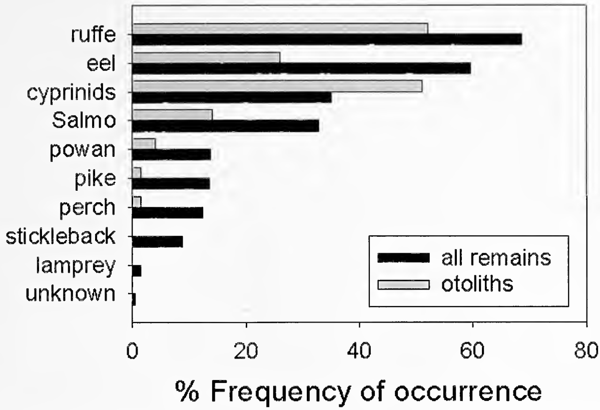


Fig 2. Frequency of occurrence of fish in otter spraints collected at Loch Lomond in 2002. Diet was determined by counting all remains in all spraints (n = 453) and also using the occurrence of otoliths only (n = 208).

The value of different prey for otters is not only dependent on their availability but also on their energy content. Ruffe have the lowest energy content (assuming similarity with perch in the same genus) whereas eel have the highest energy content of prey taken by otters (Table 2).

Fish group	Energy content kJg^{1}	
Eel	6.08	(Norman 1963)
Brown trout	5.92	(Elliot 1976)
Cyprinids	4.82	(Beja 1996)
Vertebrate (non-fish)	4.69	(Beja 1996)
Perch	4.46	(Prévost 1982)

Table 2. Energy content of prey taken by otters.
Values are expressed as kJg^{-1} fresh body mass according to Beja (1996).

In Loch Lomond the average size of ruffe taken by otters was estimated to be 8.99 cm (range 2.49 – 15.40 mm (McCafferty, 2005) which represents an average body mass of 12.7 g (Adams & Tippett 1990). Based on the relationship between otolith width and eel body size the average length of eels taken by otters was estimated as 26.6 cm (SE = 12.8 n = 89 range 7.1 – 58.5 Fig. 3) or equivalent to 45.3 g (Martucci *et al.* 1993). This analysis indicates that the energy content of the average ruffe and eel taken by otters is 57 and 275 kJ respectively. Eels are therefore five times more profitable prey items than ruffe for otters in terms of their energy content. Freshwaters with high eel biomass are therefore key areas for otters within the park. Factors influencing eel distribution are not well understood but their abundance is thought to be greatest in still waters and otters do appear to specialise on them in these areas (Carss *et al.* 1998).

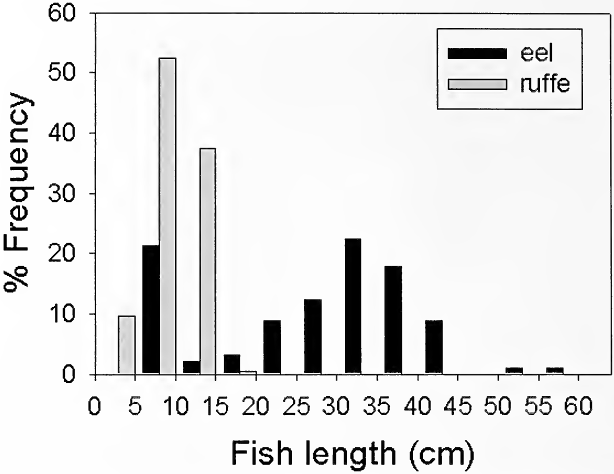


Fig 3. Comparison of the length (cm) of eel (n = 89) and ruffe (n= 208) taken by otters at Loch Lomond in 2002. Fish length was estimated using otolith size for both species (see text).

CONSERVATION PRIORITIES FOR OTTERS IN THE NATIONAL PARK

The UK Biodiversity action plan lists the current factors causing loss or decline of otters as 1. pollution of watercourses 2. insufficient prey associated with poor water quality, 3. impoverished bankside habitat features needed for breeding and resting and 4. incidental mortality, primarily by road deaths and drowning in eel traps (www.ukbap.org.uk). The opportunity of improving the conservation status of otters within the park should address each of these issues but as outlined below some of these require greater priority (Table 3). Currently, the otter is registered as an Annex II species (present as a qualifying feature, but not a primary reason for site selection) in the designation of the Loch Lomond Woods Special Area of Conservation.

	Short term	Medium term	Long term
Road mortality survey and mitigation	√	√	
Breeding records and monitoring		√	√
Habitat management		√	√
Distribution survey			√
Water quality monitoring			√
Fish biomass surveys			√

Table 3. Suggested short, medium and long term conservation objectives for otters in Loch Lomond and The Trossachs National Park.

Pollution and water quality

Although there is some controversy over the most important pollutant affecting otter populations, contamination with PCBs and / or organochlorine pesticide residues is considered the most likely cause of the widespread decline of otters in Europe (Mason & Macdonald 1986; Mason *et al.*

1992). The main source of PCBs comes from the manufacture and disposal of electrical components. Given the lack of industry within the park there are likely to be no major sources of PCBs for otters. In 1990-1 relatively high levels of PCBs were however recorded in otter spraints collected in Loch Long (Mason *et al.* 1992). The nearest source of PCBs may therefore come from adjacent marine habitats that are associated with shipping and naval activities.

Pesticides including Lindane, Dieldrin and DDT (and its metabolites) were also recorded in spraints within the vicinity of the park in the early 1990s (Mason *et al.* 1992). Given that land use within the park is predominantly for agriculture and forestry, pesticides and their residues are likely to enter freshwater systems. Dieldrin, Aldrin, Endrin, DDT and DDE were recorded in the river Leven at Renton footbridge between 2000 and 2003 (Scottish Environmental Protection Agency Harmonised Monitoring Data www.sepa.org.uk). Although the concentrations recorded were extremely low it does highlight that these compounds are present in the environment. No other pesticides have been directly linked to otter declines but the increased use of pyrethroid compounds in sheep dips may have indirect effects on otters due to a reduction in fish that have lost their invertebrate food supply (Chanin 2003). Sheep farming is widely carried out within the park and therefore any reduction in fish populations (especially eels) as a result of pesticide discharge will have an impact on otter populations.

The minimum fish biomass required to support viable otter populations in freshwater habitats is estimated to be around 10 gm^{-2} (Chanin, 2003). There appear to be no suitable data within the park to examine how otter distribution is determined by prey abundance. A small tributary of the river Almond in Perthshire close to the northern boundary of the park contained a salmonid biomass of 16.8 – 22.9 gm^{-2} (Egglishaw 1970) and salmonid and eel biomasses of 9.2 – 14.4 gm^{-2} and 0.5 – 1.6 gm^{-2}, respectively were recorded in similar oligotrophic streams in NE Scotland (Kruuk *et al.* 1993). In the long term, monitoring of fish biomass and water quality would improve our understanding of otter distribution in the park.

Habitat

The national otter surveys successfully sampled a range of habitats, and otter sites were well distributed throughout the geographical area of the park. This is a valuable long term data set for monitoring purposes and these should be continued in future years. A survey repeated each decade is probably sufficient to record long term population trends. More important may be the monitoring of how different habitats are used by otters and ways to improve their suitability. In particular, bankside vegetation and reed beds are important habitats for resting and breeding (Kruuk *et al.* 1998). The protection of these habitats or preferably an increase in the area of reed beds would have beneficial effects for otters.

Road mortalities and eel trapping

Given the extensive network of roads within the park it is likely that vehicles will kill many otters. A recent study by Green (In press) recorded 50 otter deaths on 156 km of the A75 over 12 months or equivalent to 1 death per 3.12 km per year. Main roads with large volumes of traffic account for a high mortality of otters throughout the UK (Philcox *et al.* 1999). Road mortality is greatest during periods of high river flow that cause otters to travel overland. Given that the park has more than 600 km of roads, including five main trunk roads it is expected that this will be the major human impact on otter populations within the park. A road mortality monitoring scheme is required to determine the extent of the problem and identify areas where changes to design of bridges or culverts is needed.

Although eels have been commercially fished in Loch Lomond and river Endrick, incidental mortality from by-catch in eel traps is expected to be low as the trapping of eels is scarce today (Mitchell 2001).

Disturbance

The national park is an important area for recreation and tourism and therefore what is the effect of human disturbance on otters? Chanin (2003) recently concluded that the recovery of the otter population is not being influenced by human disturbance and anecdotal evidence suggests that otters are not seriously affected by disturbance from anglers, walkers and dogs. Otters do not appear to avoid houses, industry, roads, campsites and much of the mess left by people (Kruuk 1995). The response of otters to the sounds of anglers or walkers with dogs is for otters to move to a position where they can see the source of disturbance, dive and swim underwater, then resurface and rest on the bank before resuming their previous activity a short while later (Durbin 1993). Green *et al.* (1984) also noted that that otters passed fisherman by land, underwater or through dense vegetation and then continued their activities.

Although individual otters do not appear to be influenced by short periods of disturbance there is a lack of information on how sustained levels of disturbance influences female otters with young. This may be particularly relevant in areas such as Loch Lomond where there is a high level of disturbance at certain times of the year. A main priority will be to identify breeding sites and monitor breeding success of otters to assess the effects of disturbance in different areas.

SUMMARY

Loch Lomond and The Trossachs National Park contains a diverse range of freshwaters and has adjacent marine coastal habitats suitable for otters and their prey. Otters appear to be widely distributed throughout the park and previous surveys suggest that they have reoccupied areas of their former range. The main conflict with humans within the park is likely to be as a result of road mortality. There is therefore a need to identify where road casualties occur so that measures can be implemented to reduce them. Monitoring of otter breeding sites is required to safeguard sites from habitat change or possible disturbance to females with young. Management is recommended to increase the area of important reed bed habitat for breeding and rest sites. Finally our understanding of otter distribution within the park would be improved by collecting data on fish biomass and water quality.

ACKNOWLEDGEMENTS

I thank the Vincent Wildlife Trust for permission to publish previous otter survey data and Martin Ross and Anne Jackson of Loch Lomond & The Trossachs National Park Authority (LLTNPA) for creating Fig. 1 using GIS data. Marion McCahon and Alan Bell (LLTNPA) kindly supplied relevant park statistics. Thanks to Colin Adams for help with otolith identification and useful discussions about Loch Lomond. I am grateful to the Blodwen Lloyd-Binns Bequest (Glasgow Natural History Society) for funding the diet study on Loch Lomond.

REFERENCES

Adams, C. E. & Tippett, R. (1990). *The status of the fish community of Loch Lomond.* Unpublished Report Scottish Natural Heritage.

Beja, P. R. (1996). An analysis of otter *Lutra lutra* predation on introduced American crayfish *Procambarus clarkii* in Iberian streams. *Journal of Applied Ecology* **33**, 1156-1170.

Cameron, J. M. (1981). *The food of otters (Lutra lutra) and feral mink (Mustela vison) on parts of the river Endrick within Loch Lomond National Nature Reserve from March to October 1980.* Unpublished report. Nature Conservancy Council South West (Scotland) Region.

Carss, D. N., Kruuk, H. & Conroy, J. W. H. (1990). Predation on Adult Atlantic Salmon, Salmo-Salar L, by Otters, *Lutra-Lutra* (L), within the River Dee System, Aberdeenshire, Scotland. *Journal of Fish Biology* **37**, 935-944.

Carss, D. N., Nelson, K. C., Bacon, P. J. & Kruuk, H. (1998). Otter (*Lutra lutra*) prey selection in relation to fish abundance and community structure in two different freshwater habitats. *Zoological Society of London Symposia* **71**, 191-213 Cambridge, Cambridge University Press.

Chanin, P. (2003). *Ecology of the European otter.* Conserving Natura 2000 Rivers Ecology Series.10. Peterborough, English Nature.

Conroy, J. W. H. & Jenkins, D. (1986). Ecology of otters in northern Scotland. VI. Diving times and hunting success of otters (*Lutra lutra*) at Dinnet Lochs, Aberdeenshire and in Yell Sound, Shetland. *Journal of Zoology (London)* **209**, 341-346.

Durbin, L. S. (1993). *Food and habitat utilisation of otters (Lutra lutra L) in a riparian habitat - the River Don in north-east Scotland.* PhD Thesis, University of Aberdeen.

Egglishaw, H. J. (1970). Production of salmon and trout in a stream in Scotland. *Journal of Fish Biology* **2**, 117-136.

Elliot, J. M. (1976). Body composition of brown trout (*Salmo trutta*) in relation to temperature and ration size. *Journal of Animal Ecology* **45**, 273-289.

Green, J., Green, R. & Jefferies, D. J. (1984). A radio-tracking survey of otters *Lutra lutra* on a Perthshire river system. *Lutra* **27**, 85-145.

Green, R. (In press). An estimate of the number of otters (*Lutra lutra*) killed on Scottish roads. International Otter Survival Fund. *The return of the otter in Europe*. European otter conference. Sabhal Mor Ostaig, Isle of Skye Scotland.

Green, R. & Green, J. (1997). *Otter survey of Scotland 1991-1994.* The Vincent Wildlife Trust, London.

Joint Nature Conservancy Council. (1994). *Biodiversity : the UK action plan.* HMSO, London.

Kruuk, H. (1995). *Wild otters predation and populations.* Oxford University Press, Oxford.

Kruuk, H., Carss, D. N., Conroy, J. W. H. & Durbin, L. S. (1993). Otter (*Lutra lutra* L.) numbers and fish productivity in rivers in north-east Scotland. *Zoological Society of London Symposia* **65**, 171-191 Oxford, Clarendon Press.

Kruuk, H., Carss, D. N., Conroy, J. W. H. & Gaywood, M. J. (1998). Habitat use and conservation of otters (*Lutra lutra*) in Britain. *Symposia of the Zoological Society of London* **71**, 119-133. Cambridge, Cambrdge University Press.

Kruuk, H. & Hewson, R. (1978). Spacing and foraging of otters (Lutra lutra) in a marine environment. *Journal of Zoology (London)* **185**, 205-212.

Loch Lomond and The Trossachs Fish and Fisheries Forum (2004). *Review of fish and fisheries management in Loch Lomond and The Trossachs National Park.* Balloch, Loch Lomond and The Trossachs National Park.

Martucci, O., Pietrelli, L. & Consiglio, C. (1993). Fish otoliths as indicators of the cormorant *Phalacrocorax carbo* diet (Aves, Pelecaniformes). *Bollettino di Zoologia* **60**, 393-396.

Mason, C. F. & Macdonald, S. M. (1986). *Otters: ecology and conservation.* Cambridge University Press, Cambridge.

Mason, C. F., Macdonald, S. M., Bland, H. C. & Ratford, J. (1992). Organochlorine pesticide and PCB contents in otter (*Lutra lutra*) scats from western Scotland. *Water Air and Soil Pollution* **64**, 617-626.

McCafferty, D. J. (2004). Distribution and population status of the otter (*Lutra lutra*) in the Loch Lomond area. *Glasgow Naturalist* **24(2)**, 89-91..

McCafferty, D. J. (2005). Dietary response of otters (*Lutra lutra*) to introduced prey in Loch Lomond, Scotland. *Journal of Zoology (London)* **266**, 255-260..

McCluskie, A. E. (1998). *Temperature-mediated shifts in the foraging behaviour of the Eurasian otter, Lutra lutra L.* PhD Thesis, University of Glasgow.

Mitchell, J. (2001). *Loch Lomondside.* Harper Collins, London.

Norman, J. R. (1963). Metabolism and thermoregulation in the sea otter. *Physiological Zoology* **47**, 218-229.

Philcox, C. K., Grogan, A. L. & Macdonald, D. W. (1999). Patterns of otter *Lutra lutra* road mortality in Britain. *Journal of Applied Ecology* **36**, 748-762.

Prévost, Y. A. (1982). *The wintering ecology of ospreys in Sengambia.* PhD Thesis, University of Edinburgh.

Thom, T. J., Thomas, C. J., Dunstone, N. & Evans, P. R. (1998). The relationship between riverbank habitat and prey availability and the distribution of otter (*Lutra lutra*) signs: an analysis using a geographical information system. *Symposia of the Zoological Society of London* **71**, 135-157. Cambridge, Cambridge University Press.

Watt, J. P. (1993). Ontogeny of hunting behaviour of otters (*Lutra lutra* L.) in a marine environment. *Symposia of the Zoological Society of London.* **65**, 87-104. Oxford, Clarendon Press.

Weber, J.-M. (1990). Seasonal exploitation of amphibians by otters (*Lutra lutra*) in north-east Scotland. *Journal of Zoology (London)* **220**, 641-651.

Yoxon, P. (1999). *The effect of geology on the distribution of the Eurasian otter (Lutra lutra) on the Isle of Skye.* Open University, Milton Keynes.

The Glasgow Naturalist Volume 24 Part 3 Pages 36-47 (2005).

THE FERAL GOATS OF LOCH LOMONDSIDE, WITH PARTICULAR REFERENCE TO THE INVERSNAID GROUP

Raymond Werner, Shirley Goodyer, Les Goodyer and Tracy Livingstone[1]
British Feral Goat Reasearch Group
[1]Address for correspondence: 20 Heal Cadrawd, Llangynwyd, Maesteg CF34 9TE
e-mail: feralgoatuk@yahoo.co.uk

PURPOSE OF THE STUDY

The R.S.P.B. study (1994) reached the following conclusions with regard to the antiquity, origin and type of the Loch Lomondside feral goat population:

- Possibly the oldest record of feral goats in Britain actually appertains to the Inversnaid area, this being a reference to the fourteenth century story linking Robert the Bruce to feral goats at that time.
- Feral goats would not have been tolerated in the Loch Lomondside area between around 1700 and 1920, the period when the woodlands were intensively managed for timber, charcoal and tanbark.
- It is probable that the present day feral goat herds originated around the turn of the twentieth century.
- Milking goats were liberated to join the Loch Lomondside herds at the end of the Great War, and at least three domestic animals were introduced to the Inversnaid population during the 1980's.
- There is no reason to believe that the Inversnaid population is any more or less pure than any other feral goat population.
- When introgression occurs, it is impossible to recognise domestic links in a very short space of time, it being regrettable that pelage patterns offer little evidence as to the origins of feral goat populations, or indeed as to the length of their existence.
- As suggested by Darling (1937) feral goats will revert to a wild type in a very short space of time.
- Neck tassels are present on some Inversnaid animals, and many consider this feature to be indicative of more recent feral goat populations.

Although the foregoing was presented as isolated statements in varying contexts under varying headings, it is possible to draw them into one statement that covers the only known study dealing with all aspects of the antiquity, origin and type of the Loch Lomondside feral goat population. This is paraphrased and interpreted as:

Quite possibly, the oldest records of feral goats in Britain pertain to the Inversnaid area, although the intensive management of woodlands between 1700 and 1920 would have *almost certainly* meant that feral goats were *not tolerated* in the Loch Lomondside region for a period in excess of two centuries, thus breaking any possible historical links between, and continuity with, these earlier records.

The conclusion reached, therefore, is that the present feral goat populations originated around the turn of the twentieth century, and although having a known continuous history in excess of one hundred years, the release of milking goats in 1918, and the further release of domesticants of Modern type in the 1980's, has resulted in introgression of the original stock with goats of improved type early on in the populations' more recent history.

Although the general history of the goats is considered to be quite straightforward with regard to documented sources and personal knowledge,-this being summarised as a long but discontinuous history, marked by contamination by stock of improved type- what may or may not be learned from a study of phenotype is ambiguous. Most certainly, the presence of tassels in some animals would *suggest* that the goats have a more recent origin, whilst pelage patterns offer *little evidence* with regard to either the origin of these goats or the length of their existence.

Referencing the research of Darling (1937) it is acknowledged that domestic goats will revert to a wild type in a very short space of time, so that it would be virtually impossible to recognise any domestic goat links in the Loch Lomondside population if releases or escapees have been intruded as recently as ten years ago. Thus, the phenotype of the Loch Lomondside population will have an appearance of antiquity, with a standard feral goat phenotype, irrespective of the proportion of introgression and how recently it happened. There is therefore no reason to believe that the Loch Lomondside population is any more or less pure than any other feral population, another way of disclaiming any possibility of proving that the Loch Lomondside goats are on a cline between pure Old British Primitive goat and mainly domestic stock of Modern improved type.

The following consequence could be added as a rider to the above:

This, of course, would apply to any feral goat population if it were true of the Loch Lomondside stock, and devalue our surviving feral goat populations as possible survivals of an early and primitive breed worthy of preservation; one which would be on a par with the Soay sheep with regard to antiquity and both historical and agricultural importance.

The purpose of the present study is to both take a close look at the historical evidence and to research the phenotype of the Loch Lomondside feral goat population, using the

information gained to revaluate the eight conclusions, quoted above, of the RSPB report of 1994.

NINETEENTH CENTURY DESCRIPTIONS OF THE OLD SCOTTISH GOAT

The Old Scottish goat is at best a variety of the Old British goat, the only breed found in the British Isles from the earliest introduction of livestock to the late eighteenth century, when breeds from mainly Africa, the Middle East and Asia began to trickle in by way of the larger seaports. European breeds of mainly Swiss type and origin supplemented these in the late nineteenth and early twentieth centuries.

According to Pegler (1875), the author of the first book in the English language that was devoted entirely to the subject of the goat, Scottish and Irish goats closely resembled each other, the only difference being in point of size, the Scottish being rather smaller. He offered no description of the Scottish goat at this time, but remarked that the Irish were mostly large animals with long shaggy coats. They were generally of a mixed black and white colour, with rather short ears and horns that pointed upwards. Overall, their appearance was said to have been by no means prepossessing. Pegler's observations were a reprint of a series of articles that had appeared in the *Bazaar, Exchange And Mart* in 1873, the time when, according to him, 'large numbers are imported from Ireland annually into this country'. Although Pegler wrote that in Great Britain each country seemed to have its own variety of goat- as in Irish, Scottish, welsh and English- he made it clear that not only did the Irish and Scottish resemble each other closely, but also that the English resembled these two in similar measure. As he put it: 'I have seen many goats that were called English but which as much resembled the Irish and Scottish as these animals themselves'.

Pegler again, but in the third (1886) edition of his *Book of the Goat*, described the Scottish goat as being small, long-haired and with large horns that grew back in a graceful curve towards the rear like those of the Ibex or Wild Goat. He considered the ears to be sharply "pricked", and there was a tuft of hair over the forehead like that found in Highland cattle.

Bird (1910) offered a fairly detailed description of the Scottish goat. His 'pure-bred Scottish goat' had a shaggy coat, and was a small and extremely active animal. The coat was longer than that found in the Welsh, and the horns larger and curving gracefully backwards. The forehead was fringed or tufted, and the ears were said to have been more like those found upon the Scottish sheep than of 'the heavier type usually seen in the goat'. Bird compared the Scottish goat with the Highland breed of cattle, stating that it 'admirably matched' the Highland, the resemblance probably being due in a measure to the similar conditions of locality and climate that these two classes of animals had to face. Indeed, he speculated that if the breed had been persistently bred in England, it would probably have lost in a great measure its characteristic coat.

ORIGIN AND HISTORY OF THE LOCH LOMONDSIDE FERAL GOAT

Introduction

Gibson (1954, 1972) regarded the Loch Lomond, Loch Ard and Ben Venue goats as three parts of what he termed an extended colony. Whitehead (1972) mentioned that goats were reported at Corriegrennan, which is about halfway between Ben Lomond and Ben Venue, whilst Gibson, same year, stated that goats often used to be seen in the Loch Ard area, apparently travelling between the two Bens. From this information, Gibson deduced that there was obviously some interchange between the two colonies.
In 1994, there were three centres of population in the Loch Lomondside area. This centred on the Inversnaid population, with tentatively associated populations of feral goats to both the north and the south. In the past, these populations have been known as the "Stirling" population, and, in 1972, was considered by Whitehead to number between seventy and one hundred, a figure close to Greig's one hundred of 1968 (Greig, 1970), with no more than twenty-five of these being in the Inversnaid area. Between three hundred and three-hundred-and–fifty goats of the Stirling population had been culled by the Forestry Commission the 1960's, and the total population was put at around three hundred in 1983 (information from R.J. Sater, quoted in Hellawell, 1994). The total Loch Lomondside population was put at around three-hundred-and-fifty goats in 1994. This included around two hundred animals to the south (Ben Lomond) and fifty animals to the north of Inversnaid at an as yet unidentified location.

Although there was, in the early 1990's, a scarcity of information concerning emigration and immigration, it was suggested that movements to and from these neighbouring populations were very restricted (Hellawell, 1994), although there were records of new animals appearing elsewhere. This was considered rare, however, and in general the Inversnaid population was thought of as being relatively sedentary. One factor that restricts movement in and out of Inversnaid from the south is a deep ravine (Arklet Water) combined with a deer fence. Likewise, a new stock fence to the north was anticipated to reduce goat movement in or from that direction. Even so, Hellawell qualified these statements by pointing out that in the case of the Inversnaid population there was hard evidence that some inward migration of animals from neighbouring herds did occur. This was thought to be infrequent as occurrences, but more than adequate to maintain the diversity of the gene pool.

Glen Falloch

Gibson (1954, 1972) stated that goats had then been known to frequent the hills of Glen Falloch, to the north of Loch Lomond, for at least one hundred years. Anderson (1952) gave a good description of the herd as it existed in 1899, the number then being around a dozen (ten to twelve) animals. Anderson indicated that the goats were fairly wide-ranging, including the slopes of Beinn Chabhair, and the neighbouring Braes of Balquhidder. He saw this "little herd" on ten occasions over a six-month stay in the area, and described them as being all of the same dull grey colour. The one grown male was a handsome animal with a fine pair of horns. They did not mingle with the sheep,

although the sheep and the goats were in no way shy of each other. Gibson confirmed that, around seventy years later, it was certainly still the case that the Glen Falloch goats did not seem to stay long in any one particular place. Gibson also believed that a comment made by Anderson in relation to the goats and sheep was of particular interest, as it suggested the exact opposite of the usual relationship claimed between these two species. The comment was that the local shepherds "did not like the wild goats coming about, for the sheep were liable to follow the goats' example in seeking tempting tufts of green on dangerous ledges, and sometimes sheep had to be rescued from places from which they could not extradite themselves". Gibson saw only one goat in the locality in 1971, although he did not search further east and believed that others were "temporarily absent". Whitehead (1972), made no reference to the Glen Falloch goats by this name, but commented that from time to time since the late nineteenth century, goats have been seen on mountains between Glen Falloch and the Braes of Balquhidder, including Beinn Chabhair, but seldom seem to stay long.

Inchlonaig

Buchanan Smith (1932) commented that "as to whether there still exist wild goats on the islands of Loch Lomond is a bit uncertain". Boyd Watt (1937) wrote of a tradition that wild goats inhabited the yew-tree island, Inch Lonaig, on Loch Lomond, whilst Gibson (1972) noted that this was more than a tradition. Colquhoun (1841) gave a rather graphic description of goat stalking on this island, which centred on a particular precipice that had been called from time immemorial Crap-na-gower, or the Hill of the Goats. Colquhoun made the interesting comment that at the time he was stalking the herd, the herd itself was deteriorating, "the fine old wild ones having been killed off, and some of the tame kind substituted to cross the breed". It was also Colquhoun's view that the original goats were a breed between the Welsh and the Highland, and were very large. Inhabitants did not recollect when they had been introduced, although Paterson (1893) commented that about the middle of the seventeenth century, Inchlonaig was laid waste for use as deer forest, its condition until the time he wrote, and that in the following century (the eighteenth) fifteen Highland goats were introduced onto the island. It was the descendants of these goats that remained on the island in a wild state for a long period thereafter. By the time that Paterson wrote in 1893, the goats were extinct, only fallow deer being found there at that time. According to the *British Association Excursion Handbook,* number 6, published in 1928, the yew trees were said to have been planted on the instructions of King Robert the Bruce to supply bows for archers. This is mentioned as it has been suggested that the goats were exterminated because of their destruction of the yew trees. Hansard (1841) has refuted any idea that yew trees were planted on the island to furnish bows, however, stating that a yew tree would hardly supply a half dozen staves over a period of a century's growth. Gibson confirmed that there were no feral goats on Inchlonaig in 1972, adding that he knew of no other islands in Loch Lomond where they occurred.

Achray

Watt (1937) treated the Ben Venue and Achray goats as separate populations. His reference for Ben Venue is Buchanan Smith, who does not mention Achray. Watt's reference for Achray is Wallace (1923) who stated in his appendix V the following: Three heads of bucks, shot from this flock on Achray, Callander, are shown in plate CCXXIII. b. These billies were shot by Captain R.T. Hinckes, of Foxley, Hereford, game tenant, 1922. "This flock" refers to having just discussed the Ben Venue goats, so it is evident that Wallace himself regarded the Achray and Ben venue goats as one flock. The published photographs of these billies in Wallace clearly show goats of the Old British, and therefore not Modern, type.

Ben Venue

According to Buchanan Smith (1932), the goats on Ben Venue were mentioned by the poet Southey, who refers to them as having become wild. In 1819, there were about forty of these goats. Gibson (1972) elaborated on Southey's reference to both Ben Venue and the goats in the poet laureate's journal. According to Southey "last year the Duke of Montrose sold the woods on Ben Venue, which was then completely clothed with fine trees, for the paltry price of £200. It seems incredible that for such a sum he should have incurred the obloquy and the disgrace of disfiguring, as far as it was in his power to disfigure, the most beautiful spot in the whole island of Great Britain. There are goats upon Ben venue, which have become wild, but are still considered private property. The boatman supposed them to be about forty. I wish they may be allowed to multiply. The extirpation of wild beasts from this island is one of the best proofs of our advanced civilization, but in losing those wild animals from which no danger could arise, the country loses one of its great charms."

Gibson (1972) confirmed that the Ben Venue goats had most certainly been known for generations, but added that their fortunes had fluctuated a great deal. At least fifty had been counted in 1898. In 1913 there were at least thirty. From this point onwards, a considerable increase took place, and there were probably around one hundred in the herd by the late 1930's. It is evident that billies from the Ben Venue herd were trophy shot in the last century, as apart from the Achray reference above, a head from an Achray goat is recorded as a trophy in *Records of Big Game* (Ward, 1928), and in the 1920's and 1930's, the columns of The field magazine contain several records of goat heads shot on Ben Venue. It is said that a few of the Ben Venue goats used to be white, and the billy shot on the Ben on 31st August, 1922, with horns twenty-eight-and-one-half-inches long, thirty-three inches wide, tip to tip, and seven-and-one-half-inches in circumference at the base, was of this colour. There was considerable shooting of these goats during the Second World War, their number having been reduced to thirty by 1945. Gibson (1972) could find only a half-dozen scattered goats over the whole area in 1950, and Whitehead (1972) put their number at eight in 1951. Gibson believed that the herd was by then virtually extinct, and Whitehead stated that, by 1959, only one nanny and her kid remained. Between the early 1950's and the early 1970's, Gibson had

only a very few records of goats in the Ben Venue area. However, in 1970 and 1971, he saw three goats on Ben Venue, and was told locally that there were "quite a few back now". Quite what this meant was a puzzle to him.

Buchanan Smith commented, in 1932, that as many as fourteen had been seen recently, amongst which were two black ones, one of these being a kid.

Wallace (1923) stated in appendix five of his *Farm Livestock of Great Britain* that "on the authority of Mrs. Duncan Ferguson, seventy-nine years of age, a Gaelic-speaking native of the Brig ef Turk district, wild goats, mostly light grey but some dark brown, have existed on Ben Venue since she remembers, and for generations before her time".

Grieg (1970) commented that the Forestry Commission was responsible for both exterminating the Ben Venue population and drastically reducing the numbers of the Ben Lomond population. Whitehead (1972) confirmed the culling of the Ben Venue goats by the Forestry Commission.

Ben Lomond

Due to the Robert the Bruce tradition, Whitehead (1972) ascribed a six hundred year history to the Ben Lomond goats (see under Inversnaid). He went on to state, however, that the present stock appears to have a more recent origin.

According to "local History", as Gibson phrased it, the Ben Lomond goats were virtually exterminated round about the turn of the twentieth century. They were re-established by local domestic goats going wild or being liberated. Whitehead (1972) tells a similar story, stating that at the beginning of the twentieth century, there were only a few goats in the area, the present stock being descended from domestic goats originally kept at Inversnaid and Frenich.
Gibson (1972) stated that the fortunes of the Ben Lomond goats have fluctuated enormously. Before the Second World War, the population of the herd was considered to have been at least two hundred and fifty animals, (Whitehead put it at over three-hundred) but both during and after the war, the Forestry Commission considerably reduced their numbers. Fifty were seen in 1947 (Airey, 1948), although Gibson counted barely forty in 1951. Whitehead, however, put the total in 1952 at about seventy to one hundred. From this point onwards their numbers slowly increased again, and during the 1960's the herd seemed to have numbered about one hundred goats. It was remarked, however, that they were so often widely scattered that it was sometimes far from easy to be sure of an accurate count.

Milking goats released from the disbanded First World War army camp near to Loch Ard are said to have joined the Ben Lomond goats.

At the time that Greig made his study of the Ben Lomond goats, in the late 1960's, a Forestry Commission drive was organized to round up a number of goats and to relocate them in Glen Nevis. Seventeen in all were captured, although the removal did not take place as it was decided that the goats could not be removed from one conservancy to another, this contravening a Forestry Commission regulation. These goats were re-released on Ben Lomond, and as it was felt that there were too many here, a cull by shooting was organized for the near future.

For Greig (1970), the fact that he encountered a significant number of Ben Lomond goats with tassels tended to confirm that there had been some Modern genetic stock added. Establishing the origin of this introgression proved to be difficult, however, as the older inhabitants of the area had either moved out or died by the time he carried out his study. By relying on second-hand information, he learned from a member of the Nature Conservancy staff, who had in turn heard it from an old farmer, that it was the practice until at least the 1920's to add new billies to the feral stock to "improve" the "blood". These billies were apparently purchased at the local mart, and Greig speculated that this might have been how the tassels came to be found in the Ben Lomond population during the 1960's. Greig appears not to have heard the story of the Loch Ard army camp during the Great War, and billies introduced prior to the 1920's are as likely to have been of the Old British primitive breed as of Modern type. Even had goats of Modern type been introduced on occasions prior to 1918, it is at the least probable that the Loch Ard introduction would to have to all intense and purposes swamped the existing stock with Modern characteristics by comparison.

A coloured photograph, published source unknown, but dating to the 1960's, shows two kids on Ben Lomond "one thousand feet above sea level". Both appear to be basically black, although there is considerable grizzling, which affects the tail, quarters, neck and chest, face and forehead. This is difficult to interpret as a colour pattern, although feral kids born black with grizzling in other populations have been observed to mature as black goats. Whether this grizzling is actually a roan, and therefore white hairs, or a dilute tan is hard to say, although the latter is the more likely. There is a colour pattern that is a roaning of tan and black hairs, called mahogany (Amh- also called sooty in sheep), this being an even distribution of the eumelanin and phaeomelanin hairs throughout.

Gibson (1972) counted 106 goats in 1971, twelve of which were pure white, whilst Whitehead gave a "recent" estimate of their numbers in 1972 as being 140-200.

Whitehead considered their "headquarters" to be on the steep eastern scarp from Rowardennan to about the county boundary (Stirling-Perthshire) beyond Inversnaid. The main concentration was located near to Ptarmigan; they were also seen on Craig Rostain. Also see Gibson and Mitchell (1986).

It was estimated that there were around two hundred goats in the Rowardennan/Ben Lomond population in 1994 (Hellawell, 1994).

Inversnaid

Goats at Inversnaid are said to possess the longest pedigree of any feral herd in Scotland, and Buchanan Smith (1932) asserted that they could even be termed "royal". He quoted

the story of how, in the fourteenth century, King Robert the Bruce was fleeing from his enemies and hid in a cave in Inversnaid. Whilst he was there, some wild goats came and lay down at the entrance. His pursuers, seeing the goats, believed that Bruce could not be in the cave and passed on. The King then issued a decree that the wild goats should never be molested.

It is known that at least three domestic goats have been introduced into the Inversnaid population, all seemingly in the 1980's.

In 1994, the population consisted of seventeen males, forty-six females and twenty-six kids, a total of eighty-nine animals (Hellawell, 1994).

Loch Ard

On the southern slopes of the hill at Ledard, which lies to the north side of Loch Ard, the incoming tenant in the year 1875 was required to pay valuation prices for more than twenty goats. They were not actually produced at the time of the tenancy agreement, but were certified to be on the hill. Even so, these goats never came in with the sheep at the time of the gatherings, but during the hard winter of 1878-9, they were brought in to be fed but refused to eat and had to again be given their liberty. These goats, according to Buchanan Smith, (1932) were supposed to nibble the green sprouts in dangerous cliff areas, so as not to tempt the sheep into places where they would have to be rescued with ropes.

During the Great War, there was an army camp near to Loch Ard, and here milking goats were kept. When the camp was disbanded, these goats were liberated, and were said to have joined the herds on both Ben Venue and Loch Lomondside (Ben Lomond).

It was Gibson's' view in 1972 that although small groups of goats were then to be seen in the Loch Ard area, they did not seem to remain long in the one place, and were thus presumed to be travelling between Ben Lomond and Ben venue. This led Gibson to believe that such sightings could hardly be described as a separate colony near to Loch Ard. Gibson encountered no goats in the Loch Ard area in 1971, and the recent reduction of goats on Ben Venue convinced him that it would become rare for travelling parities of goats to be seen in the Loch Ard area.

DESCRIPTION

Horn type and colour

During the late 1960's at least, the general horn type was "dorcas" on Ben Lomond (Grieg, 1970). Two colour types in horns were found on Ben Lomond, dark brown or black in coloured goats, and translucent pink or amber in dominant white goats.

Horn length and size

According to Whitehead (1972), an eight-year-old a billy shot at Rowardennan by D. Barry in September, 1951, had horns with the following dimensions: a length of thirty-two and three-quarter inches, a circumference at the base of seven inches, and a span, tip to tip, of thirty-three inches. Barry also shot a nine-year-old billy at Rowardennan in July, 1958, whose horns had a length of thirty-six and three-eighths inches, a circumference at the base of seven and one-eighth inches, and a tip to tip span of thirty-nine inches. Prior to that, in 1947, Barry had shot another eighth-year-old billy at Rowardennan with horns thirty-one inches long, a circumference at the base of eight-and one-quarter inches, and a span, tip to tip, of twenty-eight-and–one-quarter inches. Prior to the extermination of the Ben Venue goats, W. Joynson shot, in 1937, a seven-year-old male with horns that were 28-and–one-quarter inches long, and with a tip to tip span of twenty-nine inches and circumference around the base of seven-and-nine-sixteenth inches. Six years later, in 1947, Joynson had shot an eighth-year-old billy at Inversnaid with horns thirty-one-and–a–half inches long, a circumference at the base of eight-and-five-eighths-inches, and a span, tip to tip, of thirty-one inches. Lastly, Barry shot an eight-year-old billy on Ben Lomond in 1956 that had horns thirty-three-and –one-half inches long, with a circumference at the base of seven-and-five-eighths inches long and a span of thirty-five-and-one-half- inches.

The average horn length of these six billies, ranging in age between seven and nine years, is 32.75 inches, and the mean 32.75 inches. The average circumference at the base is 8.8 inches, and the average span, tip to tip, 32.7 inches.

These measurements were compared with those of twenty-four feral goat males that were trophy shot from a wide range of other Scottish feral goat populations (all quoted in Whitehead, 1972). The Loch Lomondside goat trophies were not significantly different, the Scottish feral goat trophies in general having an average length of 32.8 inches, compared to 32.75 in the Loch Lomondside goats; the circumference being on average 7.8 inches compared to 8.79; and the span an average of 33 inches compared to 32.7.

Tassels

Greig (1970) noticed that six out of a total of thirty goats he watched on Ben Lomond in 1969 had tassels, and when, on the 12th August, 1969, twenty-five were captured, he found tassels on six.

Colour and colour pattern

Two, out of a total of fourteen goats seen on Ben venue in 1932, were black.

Greig (1970) stated that ten percent of the Ben Lomond goats were pure white and that piebald goats were very rare. He described most of the Ben Lomond goats as being Toggenburg patterned except for the belly, which was usually white. What Greig termed Toggenburg pattern (technically "Swiss markings" or "Swiss patterning") is dark-bellied, and Greig called the patterning he encountered on Ben Lomond "modified Toggenburg" as the goats were white-bellied. Greig described one family group on Ben Lomond as consisting of an old white nanny, and a yearling white nanny with her pure white kid. He also mentioned

that in early 1968, the only white billy in the herd at that time died; whilst in February of 1969, he removed a brown nanny kid with Toggenburg markings plus a white belly from her pure white mother. Greig went on to speculate that if the white is dominant and the brown hypostatic, then this nanny must have been heterozygous in respect of white and modified Toggenburg. "Her kid must then have been homozygous in respect of the genes for the modified Toggenburg pattern." Greig's conclusion is mentioned in particular because he went on to state that "in this respect, the Ben Lomond goats are valuable stock for the determination of coat colour genetics, as about 90% of them fall into one of the two basic colour patterns", presumably meaning dominant white and dark-bellied Swiss patterning, again presumably meaning brown colouring. That not all the goats were dominant white at this time was demonstrated by Greig's further comments that on Ben Lomond, the white billies could be over-shadowed by a sooty tint. He mentioned a male, which he named "Jid", that when he picked up for examination in May, 1968, was pure white from birth. This goat subsequently developed a sooty colour on the face, shoulders and spine as the summer progressed. Greig's interpretation of this was that billies tend to be darker than nannies in the same herd, and thus the darker "shadow" on the white Ben Lomond males may be an "example of this tendency", presumably being a form of sexual dimorphism. What Greig described, however, was a perfect example of the colour pattern "black mask", an allele (Abm) in the agouti series that produces a near-white phenotype with a dark (black) dorsal stripe, black face mask with white stripes, and a dark spot on the brisket. Black mask is recessive to pure white, but dominant to the Toggenburg brown as the white of black mask is really a dilute tan. That the ten percent of goats described by Greig as being "pure" white were likely to have been so has been confirmed by his comments on horn colour. He found a dead billy on Ptarmigan Hill, Ben Lomond, in May, 1968. This animal had translucent horns and the remains of a white coat. The horns of goats with pure white coats are translucent pink or amber coloured rather then dark brown to black because the dominant white is a lack of pigment rather than a dilute tan. This applies also to pied goats (white mismarking), and in which a horn could even be striped translucently if white touches onto that part of the horn.

Two kids photographed in the 1960's were black with grizzled roaning (see Loch Lomond under origin and history). Pure white goats were seen in 1972.

During the nineteenth century, the Ben Venue goats were described as being mostly a light grey with some dark brown.

The Inversnaid population was stated in 1992 (Hellawell, 1994) to vary considerably, ranging from totally white animals to entirely black ones, with all manner of grey and brown occurring in between.

Size and weight

W. Joynson, who shot billies before and during the Second World War, told Whitehead (1972) that he shot a billy in 1937 in Corrie Na Urisgean, on Ben Venue, that weighed an estimated three-hundred-and-eight pounds. Richmond (1955) suggested that the Ben Lomond goats weighed up to three-hundred-and fifty-pounds. Whitehead himself, whilst acknowledging that there were undoubtedly larger than average goats in the Ben Lomond district, was sceptical that any reached two-hundred-and eighty pounds. He commented that the best goat reported by the keeper, George Jones, at Rowardennan, on the southwest face of Ben Lomond, weighed one-hundred-and-seventy-three-pounds. Jones also commented that, in his opinion, there would be few goats over one-hundred-and-sixty-eight-pounds. Whitehead himself went on to point out that if two-hundred-and-eighty-pound goats did then exist on the Lomond hills, it would surely have been an indication of very rich feeding and the deer would likewise have benefited. This, he pointed out, was not the case, as the deer weighed about the average.

Hellawell (1994) had no biometric data for the Inversnaid population, although he concluded, from subjective observation, that it comprised animals that were smaller in size than those found in other populations. The primary reason for this was thought to be the relatively poor food supply in the area, together with the relatively young age structure of the population. Elsewhere in his study, Hellawell discussed the way in which size and body weights in British feral goat populations differed, and that whilst this might be in part due to differing origins, evidence from other research suggested that the principal cause was varying environmental conditions. This led on to the conclusion that the relatively small body size of the Inversnaid goats was due in part to the shorter growing season encountered in this area, resulting in a relatively poor supply of food, especially in the winter. To this end, he thought that population density may also effect body size, the Inversnaid goats then having a high-density rate. Hellawell then quoted Welsh studies that appeared to contradict this research finding, adding "this observation casts some doubt on the above theory.

Coat

Coat length in the Inversnaid population is said to vary (Hellawell, 1994), although it was, generally speaking, longer in males than in females.

ANALYSIS AND DISCUSSION

Possibly the oldest record of feral goats in Britain actually appertains to the Inversnaid area, this being a reference to the fourteenth century story linking Robert the Bruce to feral goats at that time.

Although reference to feral goats at Inversnaid in the fourteenth century is not the oldest- feral goats being recorded in the tenth century in southern England, this record pertaining to the new Forest, the source being the Doomsday Book- the reference referred to must surely be amongst the earliest recorded for the British Isles.

Feral goats would not have been tolerated in the Loch Lomondside area between around 1700 and 1920, the period when the woodlands were intensively managed for timber, charcoal, and tanbark. This view is inaccurate on

historical grounds, it being recorded that the Ben Venue goats were in existence in the early part of the nineteenth century, and had a recorded and continuous history up to and well beyond 1920. Goats were actually introduced into the Inchlonaig area in the eighteenth century, and there were herds in both the Loch Ard and Glen Falloch areas towards the latter part of the nineteenth century. Lastly, local knowledge placed feral goats on Ben Lomond itself in the nineteenth century, the very fact that the goats came close to being exterminated around the turn of the twentieth century being an indication in itself of their existence in the nineteenth.

It is probable that the present day feral goat herds originated around the turn of the twentieth century. This assumption is probably based at least in part on the previous one, which has been shown to be erroneous, and possibly also to the local references pertaining to the fact that there were "only a few" feral goats in the Loch Lomond area at the end of the nineteenth century, this population being re-established by the introduction of local domestic stock (Inversnaid and Frenich) by either escape or liberation. It is clear that this population did not die-out completely, and that in other areas of Loch Lomondside there were populations that were also old-established at the turn of the last century.

Milking goats were liberated to join the Loch Lomondside herds at the end of the Great War, and at least three domestic animals were introduced to the Inversnaid population during the 1980's. There is good historical evidence for this from more than one source.

There is no reason to believe that the Inversnaid population is any more or less pure than any other feral goat populations. The reasoning behind this hypothesis was not discussed, although it is assumed that it was based on one or both of two assumptions mentioned in the same paragraph of the text. The first was that pelage patterns offered little evidence with regard to the origins of feral goat populations; the second that domestic escapees revert to a wild type in a very short space of time and to the point at which it is virtually impossible to recognise domestic links in a matter of ten years. The argument would therefore appear to be that feral goat populations are subject to introgression at unknown and varying rates, and that there is a levelling process that renders it impossible to discern these domestic links in the phenotype in a very short space of time. It is therefore impossible to assess the degree of introgression that my or may not have taken place, and thus equally impossible to make any judgements with regard to the purity of any particle population in comparison with another. The refutation of this view will be considered under the next two headings.

When introgression occurs, it is impossible to recognise domestic links in a very short space of time, it being regrettable that pelage patterns offer little evidence as to the origins of feral goat populations, or indeed as to the length of their existence.

This assertion relates to the introduction of Modern goat stock into an already established feral goat population of the Old British type (when introgression occurs). Its basic tenet is that the characteristics of Modern goat stock, which are recognizably different from those of the Old British goat, are absorbed into the feral type (impossible to recognize domestic links) in a very short space of time. The consequence of this is that pelage patterns would offer little evidence of either the origin or antiquity of the Inversnaid feral goat population.

Eleven basic colour patterns have generally been recognized in the goat, with a further one identified by the present writer more recently (Werner, 2003). Of these, two are found in goats of Swiss origin- no pattern white/tan and Swiss patterning. It has yet to be established that no pattern white/tan is found in the old British goat, whereas Swiss patterning is definitely not found in it. It would therefore be possible to detect the presence of Swiss breeding in the Inversnaid population by colour patterning, no pattern white/tan being the top dominant for colour, and Swiss patterning the top dominant for patterning.

With regard to the Loch Lomond goats generally, there may have been some confusion with regard to the type and extent of Modern Swiss influence both historically and more recently. Greig (1970) described white in the Rowardennan group, but mentioned also a white kid that developed the markings typical of the black mask patterning. He also described a colour pattern as being Toggenburg with a white belly. "Toggenburg" is Swiss patterning with the usual black pelage colour replaced by light brown at the brown locus. It has a dark belly. Greig's light-bellied "Toggenburg" may therefore have been a co-dominant cross between a Swiss pattern with the light brown allele and a lightbelly pattern, which gives a typical Swiss pattern with a white belly as described by Greig. Alternatively, this colour type could have been a typical lightbelly, which is black with striped legs, white belly, rump and facial markings that have the light brown allele. This brings us to the Inversnaid goats, which have been described as being commonly like the British Alpine in colour and patterning. No goats fitting this description have been seen at Inversnaid, although the most common colour pattern there was lightbelly. It is therefore possible that there is confusion between these two colour types. Other colour patterns seen at Inversnaid were Bezoar and grey lightbelly, the latter often being associated with darkbelly.

"Pelage patterns" therefore tell us quite a lot about the origin and antiquity of the Inversnaid goats: which is that they are firmly based in colour types typical of the Old British goat but not found in the Swiss-based goats of the British Isles.

Pelage (colour and colour patterns) has to be taken in conjunction with other characteristics such as ear type, head shape, overall conformation, size and coat type, to make an assessment of origin, antiquity and breed type. In the case of the Inversnaid goats, these characteristics taken together would suggest that the group originated from the Old British breed, suggesting a history prior to the 1920's, and that there has been some introgression in the past. A mature male with typical Swiss patterning was seen at loch Ard, however, which fits in with the known history of that population.

As suggested by Darling (1937) feral goats will revert to a "wild type" in a very short space of time. There are four main issues relating to Darling's theory of a reversion to a wild type when domestic goats go feral. These are:

- What did Darling mean by his term "reversion to wild type"?
- What did he consider to be the mechanism for such a reversion?
- What evidence did he offer to support his theory?
- How has Darling's theory been interpreted subsequently by researchers?, leading on to a consideration of the way in which the origin and status of the British feral goat has been viewed in the light of this.

Darling's theory on reversion to wild type in domestic goats newly gone feral was published in his supplementary paper to Hugh Boyd Watt's article entitled "On the Wild Goats in Scotland", published in 1937. Entitled "Habits of Wild Goats in Scotland," the relevant section is worth quoting in full:

> The goat is an able fellow and can go feral with no difficulty and in a very short time. The reversion to wild type is rapid and ten years can make a big difference in the general appearance of a herd. What, it might be asked, is the influence on nitrogen metabolism which makes feral goats run increasingly to hair and horns until the standard of the wild goat is reached? Natural selection must be a potent factor in levelling the type of goats newly gone feral. The breeding season is early and kids appear frequently in late January and February, which is no time for young things to appear in the West Highlands. This early breeding season serves as an extremely fine mesh seive in preserving only those which suit the conditions. I have no figures on actual kid-rearing percentage in "wild" goats, but it must be small. This tends towards a stable population and it is worth remarking that the goats are distinctly local in their distribution, and there is little if any evidence of spread or extensive migration.

So, what did Darling actually mean by the term "reversion to wild type"? It is clear that he believed that all established feral herds were characterised by long hair and long horns, and that hair-length and horn-length was consistently longer than that found in the domestic goat under domestic conditions, hence his use of the term "standard of the wild goat". Reversion to the wild type therefore meant the consistent way in which domestic goats going feral underwent an increase in hair and horn length, and that there was a standard, in terms of length, that was consistently reached. Does this imply, therefore, that Darling considered longhaired and long-horned feral goats to have originated from shorthaired and smaller-horned domestic stock? The answer to this question is clearly no, and for reasons found elsewhere in the article and its supplement.

Darling's views on a reversion to wild type were based largely on what he called the "fine herd of pure white goats which lives on An Teallach, the precipitous mountain near my home". He called this group a modern example of goats going wild, and stated that they were very wild indeed, even although the foundation stock of this herd had been owned by a crofter on the shores of Little Loch Broom as recently as ten years previously (hence his comment that "the reversion to wild type is rapid and ten years can make a big difference to the general appearance of the herd"). Watt mentioned that the crofter on the north shore of Little Loch Broom kept goats "of the wild type", and Darling himself stated that the crofter "who keeps goats of the wild type" on the north shore of Little Loch Broom had begun recently to catch up the bucks at the beginning of August and to keep them penned until November in order to overcome the early kidding problems. Relevant to this is Watt's further comment that at Kildonan (Badrallach) there was a flock of about forty goats owned by a shepherd, and that these were "indistinguishable from wild goats." All this would suggest that both Darling and Watt were perfectly well aware that domestic stock in Wester Ross as late as the 1930's was of the same type, including general hair-length and horn-length, as the feral goat or " wild type." Also, when Darling commented on the way in which the An Teallach goats had run to hair and horn until the standard of the wild goat was reached, he was perfectly aware again that the foundation stock for this exemplary group of the wild type had originated from a flock that itself was of the so-called wild type.

What, we may then ask, was reversion to wild type all about in the An Teallach group? Watt described the An Teallach goats as the most magnificent of their kind that Dr. Darling had ever seen. They had strong horns of a wide spread, very long thick coats and exceeded in size any other wild goats in the west. There were, even so, only ten to a dozen of them, and this after they had been feral for a decade. The herd composition, according to Darling, was one mature buck, yearling bucks and half a dozen nannies and their kids of the year. How a herd composition of this type came about in ten years is open to question, although given the possibility that the foundation stock comprised, say, one male and two females, all two years old; that the fertility rate was a consistent 0.5 and the ratio of male to female kids was consistently 1:1; that females bred firstly in their second year and until their eighth year; that the foundation stock was all dead by 1937, and that no major accidents or disasters befell the group, the likely population structure of the An Teallach goats after their first ten years of existence would have been five mature males aged two, four, five, six and seven, plus one yearling male; six females, aged two, four, five, six and eight, plus a yearling female, and three kids. The actual population dynamics of the group, as quoted by Darling, fits this model quite well with regard to females and kids, although one wonders what had been happening to the bucks over the years. Given this model, in conjunction with the actual make-up of the group, it is possible to assume that the one mature buck was likely to have been the son of the original male, and that there were up to five generations of mature females, mother to daughter. Given the foregoing, the sample of two males and up to five females is very small in terms of assessing an overall increase in hair and horn-length over a restricted period of time of a decade, and although the goats had taken themselves above the peat line and to the highest reaches of the mountain at over 1700 feet, implying more severe weather conditions than the balmier shores of the loch, it could equally be argued that the foundation stock

and restricted bloodlines may have had equal bearings on the way in which the herd was developing over the period. What Darling was implying by his term "reversion to wild type" in relation to an increase in hair and horn length to a wild standard must therefore be viewed in the light of Darling's knowledge that domestic goats in the West Highlands were indistinguishable from the feral type, and the group in particular that he used for his limited study originated from domestic stock that was well-known to him and already of the "wild type" before they went feral.

When considering Darling's mechanism for reversion to wild type, it should be noted that he made two separate comments on this. He noted, firstly, that goats will go feral very quickly and with no difficulty, and that it was an "influence" on the nitrate metabolism that triggered increased hair and horn growth, once they had. Darling therefore ascribed the changes in hair and horn growth to a chemical process within the organism, and one that would have affected the synthesis of the proteins, carbohydrates and fats that form tissue and store energy. But what conclusion did he reach with regard to "the influence" itself? His immediate answer was "natural selection". Natural selection was the potent factor that levelled the type in goats newly gone feral, meaning that survival of the fittest meant that only the fittest survived, the ultimate criteria for which was the fittest having longer hair and horn length.

Did he then mean that levelling out targeted the pre-existing stock over a period of time (adult mortality) or subsequent generations (passing on the best suited characteristics)? The latter, it would seem (although he viewed the process as rapid) for he immediately went on to discuss the early breeding season of the feral goat. The early breeding season was a "fine mesh sieve" that preserved only those kids that were most suited to the (weather) conditions. What we have, therefore, is the assumption that when goat stock goes feral, the adverse weather conditions during early kidding result in only those kids best suited to live in such conditions surviving; and that such kids are presupposed to have a metabolism that runs to longer hair and longer horns than is the usual standard for both those kids that tend to survive to weaning and those that don't. Darling did not, of course, discuss the issues around the heritability of all this, which is to say why characteristics that develop only in later life have such an impact on survival at the kid stage of development. His case would appear to rest on whether or not the An Teallach group had been in existence for long enough for natural selection to have weeded out those adults that were less suited to life on the bleak and exposed mountain top, i.e. those with thinner coats and less cashmere, allowing those most suited to the conditions to pass on their more suited coats to subsequent generations.

Unfortunately, Darling himself never made this case, and made no attempt to explain how or why the inherited potential to develop longer hair and horns would have such a marked effect on whether or not a goat survived the first few days of its life. Most certainly it is the case that a shorthaired goat may well develop a six-inch coat in adverse weather conditions, but the foundation stock of the An Teallach group were already long-haired at the time of their liberation, and even had they not been, the increase in hair-length would have been of a noticeably different type and texture to the coat of a genetically long-haired animal. Lastly, it should be noted that the crofter's domestic goat stock at nearby Loch Broom, had a similar early breeding season to the An Teallach group, this causing early kidding problems that needed to be overcome. This being the case, there should have been nothing unique about the early kidding in the feral goats, and any natural selection being exerted on the ferals would have equally been exerted on the nearby domesticants, another way of making the point that had Darling's mechanism for a reversion to a wild type existed in the way in which he defined it, it would have been operative before the goats went feral, thus denying any link to the process of "going wild".

The actual reference to "reversion" is an interesting one, as the obvious question is reversion to what? The genuine wild goat is shorthaired, and it has been pointed out already that Darling meant the Scottish feral goat when he alluded to a "wild standard". The best explanation of what Darling meant when he used the term is therefore the idea that goats going feral begin to look more and more like goats that are already feral until they look exactly like them, and that it is the conditions under which they are feral that makes them ultimately all look alike. Although this is the only reasonable interpretation of the meaning behind Darling's concept of a "wild type", he actually denied its validity when he made it clear that he understood that the standard of the wild type existed in domestic stock even before it had the opportunity to go feral.

Despite the fact that Darling had observed the development of a feral herd over ten years, he maintained that he had no actual figures for kid-rearing percentages in wild goats, and also made comments on the behaviour of feral goats, based on the An Teallach group, that were inaccurate (herds are patriarchally led; males remain with the females throughout the year; yearling bucks remain on the outskirts of the group; herd composition is one buck and half a dozen nannies).

Summarizing Darling's theory on reversion to wild type, it is clear that it was based on limited observation, and that at best its interpretation is that already long-haired and long-horned domestic goats, of what he called the wild type but in domestication, might develop coats and horns that are longer still if they are allowed to go feral.

Moving on to the way in which Darling's theory has been interpreted, it has mostly been taken to mean that if goats of any breed or type, or a mixture of any breeds or types, are allowed to go feral, then they will rapidly revert to a uniform and recognisable type which is long-coated and longer-horned. Often this is stated in derogatory terms, for example "little, course-horned and hairy", and pedigree goat breeders have tended to interpret the term reversion, in this context, as their fine pedigree stock reverting to a useless and non-pedigree scrub type of goat almost as soon as the refinements and blessings of Herd Book status and regular supplements are denied them. Indeed, it was reported recently that feral goats "are just mongrels…that are kidding at a year old and, no doubt, carrying a worm burden and often fluke as well" (Whiteside, 1998). Obviously, if Darling's theory had been demonstrable from

the evidence he offered, and a mechanism for its working convincingly presented, then a case would have been made for believing that "reversion to wild type" adequately explained why feral goats tended to have a predictable phenotype, and there would be no need to look beyond a *pot pouri* of domestic escapes of modern type to explain their origins. As it stands, Darling was unable to do this, and his theory was refuted as long ago as the late 1960's (Werner, 1967; Greig, 1970), although this has not stopped innumerable writers and researchers alluding to it as an assumed fact in the intervening thirty-odd years.

Lastly, little thought seems to have been given to the fact that feral goats are not universally longhaired, the standard varying between rough and thick-coated to long hair in the females and long hair in the males. What marks a feral goat of the Old British type out from the modern breeds, be they the ferals of today or the now extinct domesticants of yesteryear, is the type and texture of the coat. Not only does it appear different visually, but also is notably different when handled. Therefore, had Darling's hypothesis been viable, feral goat populations would have universally comprised longhaired animals.

Neck tassels are present on some Inversnaid animals, and many consider this feature to be indicative of more recent feral goat populations.

Tassels are generally associated with the Swiss breeds, including their British derivatives- British Saanen, British Alpine and British Toggenburg. It is therefore quite usual to consider the presence of tasselled goats in a feral population to be a good indicator, usually recent, of introgression with domestic stock of improved Modern type. The situation is a little more complex than this, however.

There is some indication that our Old British stock was tasselled, albeit rarely. Greig (1970) dealt with the matter of tassels in some detail, concluding that the references to tassels in English publications were based on translations of Continental works, where tasselled goats are not at all uncommon. Whilst this is certainly true, the present writer has come across a painting in the Museum of Canterbury by Thomas Cooper, the famous Kent artist who specialized in sketching and painting livestock, that shows a Welsh feral herd on the run. The dating is the 1840's, and whilst the goats themselves are faithful representations of the Old Welsh goat, a female is tasselled. The idea that the Old British goat could be tasselled cannot therefore be dismissed.

What should be taken note of, even so, is that a general study of nearly 1000 feral goats to date has indicated that tassels are universally absent in populations in which there is no indication of introgression, whilst tassels are present in some populations that show other indicators of introgression with Modern goat stock. This would suggest that tassels are likely to be a general indicator of introgression in the surviving feral populations of Scotland.

That the presence of tassels is also a good indicator of the *recent origin* of a population is also open to question. It is unlikely that goats of Modern type had the opportunity to enter the Scottish goat stock gene pool prior to the early twentieth century, filtering out into feral goat populations from the 1920's onwards. A population of rank antiquity, say one with a pedigree in excess of 150 years, might have had some introgression with domestic stock 80 years ago, the presence of tassels in this case being no indication of a 'recent origin'.

Lastly, tassels are a simple dominant, so that its presence in a feral population may be out of all proportion to the amount of introgression that has occurred. i.e. the introduction of only one billy of Modern type into an established population might have left a greater legacy of tasselled descendants that any other characteristic.
In the case of the Inversnaid goats, tassels may be present, but the overall characteristics of the animals would indicate that they originated from Old British stock with a later, but minor, influence of goat stock of an improved type. In this case, therefore, the presence of tassels only serve to confirm what is otherwise known, and offer no evidence as to a recent origin for the population.

GENERAL CONCLUSIONS

It is quite likely that feral goats have occurred in the Loch Lomondside area since the fourteenth century, and there is no reason to believe that they were not tolerated there between the seventeenth century and the 1920's. A continuous history is therefore likely.

Given the historical evidence, the present stock would have originated during a period when only the Old British breed was known in the Stirling area, and earlier descriptions and trophy hunted heads confirm this. Also, goats seen at Inversnaid conformed to the basic breed type of the Old British goat.

It is known that goats of the Modern type were introduced into the feral populations of Loch Lomondside at various times during the last century, and, once again, there are indications of some introgression in the Inversnaid stock.

Much reliance has been placed on Darling's theory that goats will revert to a wild type in a very short space of time, which has been found to be erroneous, and that pelage patterning is of no use in determining the origin and antiquity of feral herds. This has confused the issue, and led to the conclusion that it is impossible to determine from what type of goat the present Loch Lomondside population originates, and how long it has been there. A study of the breed type and colour patterns of the Inversnaid goats in particular, however, has been helpful in confirming the accuracy of the historical account and linking this with the present goat population. Consequently, the Inversnaid goats in particular are living history, and a valuable gene bank in terms of preserving a remnant of the Old British Breed of goat.

REFERENCES

(This list includes works consulted and a select general bibliography for feral goats in Scotland)

Airey, A. F. (1948). Wild Goats on Ben Lomond. *Country Life*, 9th January.

Alston, E. R. (1880). *The Fauna of Scotland. Mammalia.* Glasgow.

Anderson, R. P. R. (1952). Letter re Wild Goats in Scotland. *Oban Times*, 8th March.

Bird, J. T. (1910). *The Goat: its use and management.* London.

Blain, J. (1820). *History of Bute.*

British Association (1928). *Handbook for Excursions. No. 6, Loch Lomond*

Brydone, P. C. (1963). *Pine Marten, Pole Cats and Wild Goats.* Letter to the *Oban Times*, 21 March.

Buchanan Smith, A. D. (1927). *Goats for the Island of Eigg.* British Goat Society Year Book.

Buchanan Smith, A. D. (1932). *"Wild" Goats in Scotland.* British Goat Society Year book, pages 120-125.

Campbell, G. A. (1952). Wild Goats in Scotland. Letter to the *Oban Times*. 29th March.

Chapman, A., (1924). *The Borders and Beyond.*

Collier, R., (2001). Personal Communication to the Writer, 23rd October.

Colquhoun, J. (1841). *The Moor and the Loch.* Edinburgh.

Cameron, T. W. M. and Parnell, I. W. (1933). *The Internal Parasites of Land Mammals in Scotland.* Proceedingss of the Royal Physiological Society.

Cummings, L. (1929). Goats on Islay. Letter to *Country Life*, 6th April.

Darling, F. F. 1937. *Habits of Wild Goats in Scotland.* Supplement to Boyd Watt, 1937.

Darling, F. F. (1947). *Natural History in the Highlands.*

Davenport, F. R. (1941). Wild Goats on Rhum. Letter to *The Fields*. 17th June.

Dodds, W. (1952). Goats of the Borders. Letter to *Country Life*. 9th May.

Edwards, E. (1957). Wild Goats in Scotland. Letter to *Country Life*. 10th May.

Fitter, R. S. R. (1959). *The Ark in Our Midst.*

Gibson, J. A. (1972). The Wild Goats of the Clyde Area. Western Naturalist 1.

Gibson, J. A.. (1954). The Mammals of the Clyde Faunal Area. *Transactions of the Paisley Natural History Society*, 6.

Gibson, J. A. (1969). The Mammals of the Island of Arran. *Transactions of the Buteshire Natural History Society*, 17.

Gibson, J. A. (1969-70). The Mammals, Reptiles and Amphibians of Ailsa craig. *Transactions of the Buteshire Natural History Society* 17.

Gibson, J. A. (1970). The Mammals of the Island of Bute. *Transactions of the Buteshire Natural History Society* 18.

Gibson, J. A. (1970). Additional Mammal Notes from the Island of Arran. *Transactions of the Buteshire Natural History Society* 18.

Gibson, J. A. and Anderson, J. (1972). The Mammals of Renfrewshire. *Western Naturalist* 1.

Gillies, P. H. (1909). *Netherlorn, Argyllshire and its Neighbourhood.*

Glasgow and Andersonian history society (1936). Report for members in manuscript.

Gordon, S. (1935). *Highways and Byways in the West Highlands.* London.

Greig (1970). Msc. Submission on *Feral Goat Management.* Edinburgh.

Harvey-Browne, J. A. and Buckley, T. E. (1892). *A Vertebrate Fauna of Argyll and the Inner Hebrides.* Edinburgh.

Herford, C. H. (1929). *Journal of a Tour in Scotland in 1819, by Robert Southey.* London

Jarvie, J. K. (1964). Inverness-shire Goats. Letter to *Country Life*, 16th January.

Joicey, M. E. (1947). Wild Goats of Britain. Letter to *Country Life*. 24th October.

Loder, J. de Vere (1935). *Colonsay and Oronsay in the isles of Argyll, their History, Flora, Fauna and Topography.* Edinburgh.

Macintyre, D. (1936). *Wildlife in the Highlands.* London.

Macintyre, D. (1949). Letter re. Wild Mountain Goats. *Oban Times,* 8th January.

Macintyre, D. (1044). *Highland Naturalist.* London.

Macintyre, D. (1950). *Memories of a Highland Gamekeeper.* London.

Macintyre, D. (1952). Letter re Wild Goats in Scotland. *Oban Times*, 22nd March.

Mackenzie, D. (1971). *Goat husbandry.* 3rd edition.

MacKenzie, O. H. (1922). *A Hundred Years in the Highlands.*

Macnally, I. (1965). The Habits of Pinemartens, Wild Goats and Badgers. *Shooting Times and Country Magazine.* 18th February.

Martin, M. (1703). *A Description of the Western Islands of Scotland.* Modern edition, Stirling, 1934

McConnochie, A. I. (1923). *The Deer and Deer Forests of Scotland, Historical, Descriptive, Sporting.*

McTaggart, H. S. (1969). Feral goats on Holy Island, Arran. *U. F. A. W. Annual Report*, 1968-9.

McTaggart, H. S. (1970). Feral Goats on Holy island, Arran. *U. F. A. W. Annual Report*, 1969-70.

Millais, J. G. (1906). *The Mammals of Great Britain and Ireland.* London.

Mitchell, J. (1957). Wild Goats on Jura. Letter to *Country Life*, 24th October.

Moorhouse, S. (1964). The Wild Goats of Britain. *The Yorkshire Post*, 9th May.

Naismith, W. W. (1934). *The Islands of Scotland, excluding Skye.* Scottish mountaineering Guide. Edinburgh.

New Statistical Account of Scotland (1845). Volume 5, *Ayr and Bute*; Volume 7, *Renfrew and Argyle.* Edinburgh.

Niall, I. (1957). Wild Goats. *Country Life*. 24th January.

Paterson, J. (1893). Records of Excursions to Loch Lomondside. *Andersonian Naturalists Society* 1.

Pegler, H.S.H. (1875). *The Book of The Goat.* Bazaar, Exchange And Mart. 1st edition.

Pegler, H. S. H. (1886). *The Book of the Goat.* Bazzaar, Exchange and Mart. 3rd Edition.

Pennant, T. (1766). *British Zoology.*

Pennant, T. (1776). *A Tour in Scotland and Voyage to the Hebrides.*

Reid, J. E. (1864). *History of the County of Bute.* Glasgow.

Richmond, W. K. (1955). Wild Goats. *Scottish Field*, May 1955.

Ritchie, J. (1920). *The Influence of Man on Animal Life in Scotland.*

Ross, W. (1947). Wild Goats in the Highlands. Letter to *Country Life*. 19th December.

RSPB. (1994). *Inversnaid Goat Management Plan.*

Smart, A. (1932). Letter re. *Wild Goats in Scotland.* 15th January.
Smith, S. (1948). Wild Goats on Bute. Letter to *Country Life*. 30th January.
Stewart, A. E. (1933). Wild Goats in Scotland. *The Field*, 16th December.
Tegner, H. (1963). *Game for the Sporting Rifle*.

Wallace, H. F. (1949). *Hunting Winds*.
Wallace, R. (1923). *Farm Livestock of Great Britain.* Edinburgh.
Ward, R. (1928). *Records of Big Game*. Nine editions, between 1892 and 1928.
Watt, H. B. (1937). On the Wild Goats in Scotland. *Journal of Animal ecology* 6.
Watt, H. B. (1905). The land mammals of the Clyde Fauna area. *Transactions of the Natural History Society*. Glasgow.
Tegner, H. (1965). Wild Goats in Britain. *Scottish Field*, February.
Tegner, H. (1967). Goat Stalking in Scotland. *Shooting Times and Country Magazine*, 1st April.
Versy-Fitzgerald, B. (1946). *British Game*.
Wallace, A. R. (1892). *Island Life*.
Wallace, H. F. (1906). The Chase of a Goat. *Country Life,* 10th March.
Werner, R. (2003). A New Colour Pattern Identified In Goats. *The Jem*: September.
Whitehead, G. K. (1945). Wild Goats of Scotland. *The Field*, 10th March.
Whitehead, G. K. (1947). The Horned Game of Great Britain. *Country Life*. 19th September.
Whitehead, G. K. (1972). *The Wild Goats of Great Britain and Ireland.* David and Charles.
Zeuner, F. E. 1963. *A History of Domesticated Animals.* New York.

The Glasgow Naturalist Volume 24 Part 3 Pages 48-51 (2005).

STUDYING NUTRITION AND REPRODUCTION OF NESTBOX-BREEDING BIRDS WITHIN LOCH LOMOND NATIONAL PARK

Scot L. Ramsay

Institute of Biomedical and Life Sciences, Division of Environmental and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ

ABSTRACT

There are 260 nestboxes deployed in the oak-dominated woodland around the Glasgow University Field Station, Rowardennan. These nestboxes are used by four species of breeding passerine and were home to over 150 clutches of eggs in 2005 alone. These boxes and birds provide a valuable resource for ecological research and have been used in several studies. This paper presents a) some information on these nestboxes and birds that use them and b) outlines four research projects, investigating topics of current scientific interest and environmental concern, which have utilised this resource.

INTRODUCTION

Over the last several years I have been involved in a number of research projects concerning the influence of environmental nutrition on reproduction and fitness. Much of this research has utilised populations of small passerines that breed in nestboxes within Loch Lomond and the Trossachs NP and, in particular, around the Glasgow University Field Station (UFS), Rowardennan.

One of my current research projects, part funded by GNHS, uses blue tits breeding in nestboxes around UFS and I present here an outline of this project and its current status. In order to further highlight the value of the Loch Lomond NP for research, and in view of the exciting development of new research facilities at UFS, I also present some information regarding the nestboxes around UFS and a brief summary of some previous research projects which have utilised them.

NESTBOXES AROUND GLASGOW UNIVERSITY FIELD STATION

The University Field Station is surrounded by ancient semi-natural oak woodland recognised as being of national conservation importance and designated as a Site of Special Scientific Interest and a Special Area for Conservation. As a result of its managed history the tree species diversity is relatively low with a very high proportion of oak. A further consequence of management history, as with most woodlands of Western Europe, is that there are few old, dead and dying trees and, consequently, relatively few natural nesting holes.

Nestboxes

In the early 1990s 195 nestboxes were deployed in the woodland around UFS. These boxes were all of weather-resistant 'woodcrete' construction (manufactured by the 'Schwegler' company of Germany) and are ideal for research as they can be lifted down to the ground and the fronts removed for easy access to nest contents. At the end of 1993, an additional 76 nestboxes were deployed: 26 of these being 'woodcrete' and the remaining 50 being timber. In January 2004, all timber boxes were removed and replaced with woodcrete ones, giving a current total of 260 nestboxes.

Species using nestboxes

Four bird species have been observed to breed in these nestboxes: blue tit (*Parus caeruleus*), great tit (*Parus major*), pied flycatcher (*Ficedula hypoleuca*), and redstart (*Phoenicurus phoenicurus*). Blue tit are by far the most numerous species: in the mid 1990s there were 55-65 breeding pairs, rising to 93 pairs in 2004 and an impressive 120 breeding pairs in 2005. Breeding great tits generally number around 15 pairs, with less variation between years than blue tit. Numbers of pied flycatcher breeding in the area have fluctuated markedly over the last decade but for the last two years have remained at 13-14 pairs. Finally, in each year for which records are available, there has been a single pair of breeding redstart. Pipistrelle bat (*Pipistrellus pipistrellus*) and Brown long-eared bat (*Plecotus auritus*) have also frequently been observed to roost in these nestboxes during spring and summer.

ENVIRONMENTAL NUTRITION AND AVIAN REPRODUCTION

Adequate nutrition is vital to a successful breeding attempt and in many species the breeding season is timed to coincide with a particular peak in food supply. Research which examines the relationship between diet and reproduction is, therefore, a key component in understanding the interaction between species and their environment. Only armed with such knowledge can we attempt to both understand and predict the impact of environmental change. Such understanding is vital for the effective conservation of both individual species and entire ecosystems.

Summarised below are four research projects which have utilised nestboxes in Loch Lomond NP to study the interaction between nutrition and reproduction in passerine birds and to investigate issues of environmental concern.

Acid rain and calcium for eggshells (Ramsay and Houston, 1999)

The normal diet of most small passerines contains insufficient calcium for effective eggshell formation and birds must often forage specifically for calcium-rich items in the environment (Jones 1976; Repasky *et al.,* 1991). The most important natural source for temperate passerines such as tits appears to be snail shells (Ankney and Scott, 1980). It has been demonstrated that anthropogenic acid precipitation can significantly reduce levels of available calcium in soil and the abundance of calcareous items such as snail shells (Scheuhammer, 1991; Graveland and van der Wal, 1996; Graveland *et al.,* 1994). Research in areas adversely affected by acid precipitation on Continental Europe had suggested that reduced calcium availability had resulted in an

increased incidence of eggshell defects in small birds (Graveland and van der Wal, 1996; Graveland *et al*., 1994).

In 1994 Prof. David Houston and I decided to investigate this in nestbox breeding tits around Loch Lomond (Ramsay and Houston, 1999). The basal rocks of the Scottish Highlands are poorly buffered, having among the lowest calcium levels in Europe. At the time of the study, however, West-central Scotland also experienced the highest levels of acid rain in Britain. Consequently, snail abundance (0.36 snails per m^2) and exchangeable soil calcium levels (0.02 mg g^{-1}) at our study sites (Rowardennan, Tarbet & Inversnaid) were extremely low: lower than values at sites in the Netherlands where severe eggshell defects occurred. The provision of supplementary calcium and the examination of eggshells, however, provided no evidence that blue tits were constrained in their ability to form effective eggshells as a result of calcium deficiency. We were therefore able to suggest that other factors besides low calcium availability, such as industrial pollutants, may have been contributory to the high incidence of eggshell defects seen in other areas.

Climate change and phenology of bird breeding
Pan-European Pied Flycatcher study (Both *et al*., 2004): In recent years, many studies have reported advances in the phenology of organisms and this has usually been attributed to climate change. However, such studies are usually uncontrolled and observed advances could be caused by other factors, unrelated to climate change. In addition, there is likely to be a publication bias towards studies of populations that show advances.

In order to address this, Both *et al.* published a study in 2004 which drew on breeding date data from 25 long-term studied populations of *Ficedula* flycatchers across Europe. This data set included the population breeding in nestboxes around UFS. Trends in spring temperature were found to vary markedly between study sites, and across populations. The advancement of laying date was much stronger in areas where the spring temperatures increased more, giving much stronger support to the theory that climate change causally affects breeding date advancement.

Phenology of Parid breeding: In 2004 and 2005 average laying dates for blue tits breeding in nestboxes around UFS were over one week earlier than in mid 1990s. In a pan European study of great tit and blue tit (Visser *et al*., 2003), however, laying dates were found to have advanced in only 5/13 great tit populations and 3/11 blue tit populations. The observed differences between populations are, in part, due to differences in local temperature change, as with pied flycatchers, above. However, there are additional factors involved.

There are populations of tits where many pairs are traditionally double-brooded and, in some of these, birds have responded by reducing the incidence of second broods (Visser *et al*,. 2003): an advancement of the invertebrate availability window and accelerated larval development means that many pairs now have insufficient time to rear two broods. If parents are no longer trying to fit two broods into the breeding season they may start their first brood slightly later. As a consequence, it may be that no advancement of average laying date is seen in response to increased spring temperatures.

Blue tits occupy a range of habitats and their breeding interacts closely with conditions in that ecosystem. Different ecosystems respond to increased temperatures in different ways, and consequently this influences the birds breeding there. For example, in the evergreen oaks of Corsica, caterpillars appear much later in the year and blue tits breed later. Consequently, their breeding is unaffected by changes in spring temperatures. Rather, as climate is hot at the time young are in the nest, breeding is limited by water supply for evaporative cooling, rather than food availability (Blondel, 1985; Blondel *et al*., 1993). It is important, therefore, to try and understand the nature of interactions between breeding, food supply and ecosystem if one is to be able to understand or predict the outcome of perturbations to that ecosystem.

Nutritional constraints on egg production in the blue tit (Ramsay and Houston, 1999; Ramsay and Houston, 1998; Ramsay and Houston, 2003)
This was the topic of my PhD research from 1993-1997 and field work was carried out using blue tits breeding in nestboxes around UFS. Research methods included the provision of different food supplements to breeding pairs, monitoring of breeding attempts, observation of foraging and determination of invertebrate availability and nutritional value.

Our research showed that increasing natural food supply (irrespective of actual composition of food) influenced timing of breeding, by advancing laying date. Many other studies investigating parid breeding and food supply have also reported similar advancements of laying date. Tits appear to use the timing of food availability early in season to anticipate food availability for chick rearing and adjust timing of breeding in response.

Within our study population, egg production was increased by the provision of high quality protein, whilst lower quality protein and energy supplementation had no effect, suggesting that natural availability of specific amino acids could be limiting. Evidence for a nutritional constraint on egg production from other studies, however, was limited and mixed.

Analyses of nutrients in arthropod prey (Ramsay and Houston, 2003) and comparison with the dietary requirements of laying blue tits indicated that birds on a predominantly arthropod diet would be unlikely to face such a constraint: eating enough arthropods to simply satisfy energy needs should provide more than enough good protein. Supplementary feeding studies by other researchers, using both blue and great tits, in a variety of other habitats, had produced mixed results with some reporting increases in egg production and others not.

Using further observational data and additional diet information from literature, we argue that blue tits living in oak woodland face a particular problem. Different tree species come into leaf at different times and bud burst in oak trees is relatively late. Crucially, the appearance of arboreal

invertebrates in significant quantity is closely related to bud burst.

Early in a mixed wood, tits can feed on arthropods from other tree species and switch to oak later in the season when arthropod abundance has increased. In an oak-dominated wood, however, blue tits' ability to switch trees early in the season is severely restricted and they may thus be expected to experience an extremely low availability of invertebrates. The scarcity of invertebrates at the start of the laying season was confirmed by invertebrate sampling (Ramsay, 1997). Consequently, tits may also have to feed on other, non-invertebrate, food items early in the season. A study by Betts (Betts, 1955) showed that early in the breeding season, the gizzards of most blue tits in oak woodland contained over 75% plant tissue (mostly oak bud tissue) and they may consume significant quantities of other plant material such as birch sap.

This study highlights the significance of studying specific species-habitat interactions and the potential problems of generalising between populations in different habitats or between related species. The high proportion of oak trees in historically managed woodland such as that around UFS creates a very different nutritional environment early in the season than that in a mixed woodland. Similarly, whilst blue tits primarily forage in twigs and leaves, great tits will also forage to an extent on the trunks of trees and the ground litter, where arthropods tend to occur year round. As a result, great tits in oak woodland do not face the same nutritional constraints that blue tits do.

Do spiders in the diet make tit chicks fitter?

(Current research project in collaboration with Dr Kate Arnold, University of Glasgow)

Background In Blue tits (*Parus caeruleus*) and other Parids, an intriguing pattern of parental provisioning has been observed. Caterpillars generally form the majority of the chicks' diet (Perrins, 1979) with strong selection pressure for brood rearing to coincide with the seasonal peak in caterpillar abundance (Perrins, 1991). However, several studies have recorded a particularly high proportion of spiders in the diet during early stages of chick development Royama, 1970; Tinbergen, 1960; Balen, 1973; Cowie and Hinsley, 1988; Woodburn, 1997; Grundel and Dahlsten, 1991). This trend, while strongly correlated with the age of the nestlings, occurs irrespective of season or habitat, indicating that it is not related to variations in natural spider abundance. During chick rearing, spiders are much less abundant than caterpillars (Ramsay 1997; Woodburn, 1997), yet spiders are still preferentially collected in relation to their relative density (Naef-Daenzer *et al.,* 2000). So, are Parids preferentially provisioning their chicks with spiders to provide a specific nutrient vital for neonatal development?

Spiders and caterpillars have broadly similar nutritional composition, except that spiders contain 40 – 100 times the level of taurine (a free sulphur amino acid) found in caterpillars (Ramsay and Houston, 2003). In mammals, taurine cannot be made by neonates, is found in high concentrations in placenta and milk and is vital for neonatal development (Aerts and Assche, 2002). Taurine is essential for normal fat digestion and has significant effects on growth. A recent profusion of research into taurine has demonstrated that it also has antioxidant properties Wu *et al., 2003;* Aerts and Assche, 2002). Further, there is also a suggestion that it may promote the uptake of important fat-soluble antioxidants, such as carotenoids and vitamins A and E, by making them water soluble (Petrosian and Haroutounian, 2000). Antioxidants protect the body against damage caused by free radicals and can thus enhance immune function and protect against many diseases whilst carotenoids provide the yellow colouration of blue tit plumage which plays an important role in signalling. Finally, one of the best studied roles of taurine is in mammalian brain and eye development, where adequate taurine is essential for optimal development.

Our project aims to investigate the role of taurine in parid chick development and whether it is limiting, thus explaining the selective provisioning of spiders in Parids.

Methodology

Diet supplementation

Throughout early development, individual nestlings were fed once a day with either taurine supplement or control treatment. Within each nest, roughly half the nestlings were randomly assigned to the taurine-group, with the remainder as controls.

Morphological development, plumage colouration and antioxidant levels

Prior to fledging size and mass recorded; feather colouration measured using spectrophotometer; blood sample taken for analysis of antioxidant levels and health status.

Cognitive and visual performance of offspring

One taurine chick and one control chick, from each of several nests, brought into aviaries at the University of Glasgow. After hand rearing to independence, birds studied in a range of behavioural trials to examine their visual and learning abilities as well as their reactions to novelty and conspecifics. After completion, birds released at capture site.

Natural prey delivery

The frequency and relative abundance of prey types brought to broods was monitored using infrared in-nestbox video cameras. From analysis of recordings we were able to determine provisioning level of spiders to each brood and examine relationship between chick fitness and spider delivery. Further, by manipulating natural brood sizes at some nests, we could examine effect on relative spider delivery rates. Do parents respond to lower demands of reduced brood by increasing provisioning of harder to find spiders?

Funding for two research assistants to help with filming and analysis of video tapes was generously provided by Glasgow Natural History Society through the Blodwen Lloyd Binns Bequest Fund.

Results

Data from this project are currently under analysis, but we hope to be publishing some exciting results soon.

ACKNOWLEDGEMENTS

I thank the Blodwen Lloyd Binns Bequest, Natural Environmental Research Council and Leverhulme Foundation for grants to support this research; Prof David Houston for supervising my PhD and providing advice, assistance and friendship throughout PhD and since; current research collaborator Dr Kate Arnold; Prof Neil Metcalfe for information on pied flycatchers; Sarah Jarvis, Caroline Askew, Tiina Mustonen, Gabrielle Roy, Christine Oines, Christine Gould, Lindsay Henderson, Clare Toner, Stephen Larcombe, Patrick White, Anna Riach, Tessa Cole, Fiona Marchant, Ian Rickard and Guillam McIvor for invaluable assistance with fieldwork and aviary work.

REFERENCES

Aerts, L., and van F. A. Assche. (2002). Taurine and taurine-deficiency in the perinatal period. *Journal of Perinatal Medicine* 30, 281-86.

Ankney, C. D., and D. M. Scott. (1980). Changes in nutrient reserves and diet of breeding brown-headed Cowbirds. *Auk* 97, 684-696.

Balen, J. H. van. (1973). Acomparative study of the breeding ecology of the great tit, *Parus major* in different habitats. *Ardea* 61, 1-93.

Betts, M. M. (1955). The food of titmice in oak woodland. *Journal of Animal Ecology* 24, 282-323.

Blondel, J. (1985). Breeding strategies of the blue tit and the coal tit (*Parus*) in mainland and island Mediterranean habitats: a comparison. *Journal of Animal Ecology* 54, 531-56.

Blondel, J., P. C. Dias, M. Maistre, and P. H. Perret. (1993). Habitat heterogeneity and life-history variation of Mediterranean tits. *Auk* 110, 511-20.

Both, C., A. V. Artemyev, B. Blaauw, R. J. Cowie, A. J. Dekhuijzen, T. Eeva, A. Enemar, L. Gustafsson, E. V. Ivankina, A. Jarvinen, N. B. Metcalfe, N. E. I. Nyholm, J. Potti, P. Ravussin, J. J. Sanz, B. Silverin, F. M. Slater, L. V. Sokolov, J. Torok, W. Winkel, J. Wright, H. Zang, and M. E. Visser. (2004). Large-scale geographical variation confirms that climate change causes birds to lay earlier. *Proceedings of the Royal Society, London, Series B* 271, 1657-62.

Cowie, R. J., and S. A. Hinsley. (1988). Feeding Ecology of Great Tits (Parus-Major) and Blue Tits(Parus-Caeruleus), Breeding in Suburban Gardens. *Journal of Animal Ecology* 57, 611-26.

Graveland, J., and R. van der Wal. (1996). Decline in snail abundance due to soil acidification causes eggshell defects in forest passerines. *Oecologia* 105, 351-60.

Graveland, J., R. van der Wal, J. H. van Balen, and A. J. van Noordwijk. (1994). Poor reproduction in forest passerines from decline in snail abundance on acidified soils. *Nature* 368, 446-48.

Grundel, R., and D. L. Dahlsten. (1991). The Feeding Ecology of Mountain Chickadees (Parus-Gambeli) - Patterns of Arthropod Prey Delivery to Nestling Birds. *Canadian Journal of Zoology* 69, 1793-804.

Jones, P. (1976). The utilization of calcareous grit by laying Quelea quelea. *Ibis* 118, 575-76.

Naef-Daenzer, L., B. Naef-Daenzer, and R. G. Nager. (2000). Prey Selection and Foraging Performance of Breeding Great Tits Parus Major in Relation to Food Availability. *Journal of Avian Biology* 31, 206-14.

Perrins, C.M. (1979). *British Tits*. Collins, London, England.

Perrins, C.M. (1991). Tits and their caterpillar food supply. *Ibis* 133, 49-54.

Petrosian, A. M., and J. E. Haroutounian. (2000). Taurine as a Universal Carrier of Lipid Soluble Vitamins: Ahypothesis. *Amino Acids* 19, 409-21.

Ramsay, S. L. (1997). *Nutritional constraints on egg production in the blue tit, Parus caeruleus*. PhD thesis, University of Glasgow.

Ramsay, S. L., and D. C. Houston. (1998). The effect of dietary amino acid composition on egg production in blue tits. *Proceedings of the Royal Society, London, Series B* 265, 1401-1405.

Ramsay, S. L. (1999). Do Acid Rain and Calcium Supply Limit Eggshell Formation for Blue Tits (Parus Caeruleus) in the Uk? *Journal of Zoology* 247, 121-25.

Ramsay, S. L. (2003). Amino Acid Composition of Some Woodland Arthropods and Its Implications for Breeding Tits and Other Passerines. *Ibis* 145, 227-32.

Repasky, R. R., R. J. Blue, and P. D. Doerr. (1991). Laying red-cockaded woodpeckers cache bone fragments. *Condor* 93, 458-61.

Royama, T. (1970). Factors governing the hunting behaviour and selection of food by the great tit (*Parus major* L.). *Journal of Animal Ecology* 39, 619-68.

Scheuhammer, A. M. (1991). Effects of acid rain on the availability of toxic metals and calcium to wild birds and mammals. *Environmental Pollution* 71, 329-75.

Tinbergen, L. (1960). The natural control of insects in pinewoods. 1. Factors influencing the intensity of predation by song birds. *Archives Neerlandaises De Zoologie* 13, 265-343.

Visser, M. E., F. Adriaensen, J. H. van Balen, J. Blondel, A. A. Dhondt, S. van Dongen, C. du Feu, E. V. Ivankina, A. B. Kerimov, J. de Laet, E. Matthysen, R. McCleery, M. Orell, and D. L. Thomson. (2003). Variable responses to large-scale climate change in European *Parus* populations. *Proceedings of the Royal Society, London, Series B* 270, 367-72.

Woodburn, R. (1997). *Breeding ecology of the Blue Tit and Great Tit and the possible effects of climate change*. PhD thesis, University of Oxford.

Wu, H. C., C. Y. Shiau, H. M. Chen, and T. K. Chiou. (2003). Antioxidant Activities of Carnosine, Anserine, Some Free Aminoacids and Their Combination. *Journal of Food and Drug Analysis* 11, 148-153.

The Glasgow Naturalist Volume 24 Part 3 Pages 52-55 (2005).

LOCH LOMOND: A NATURAL HISTORY AND A SCIENTIFIC STUDY

Victoria Ogilvy
Castle House, Duncrub Park, Dunning, PH2 0QR.

After graduating from the University of Glasgow in 2004 with a degree in Zoology, I undertook a Masters in Biological Photography and Imaging at the University of Nottingham. As part of the MSc. I was required to complete a dissertation composed of photographs, illustrations and text. I was delighted to be offered the chance to carry out the work for my dissertation at Glasgow University Field Station, on Loch Lomondside, with Dr. Kate Arnold and Stephen Larcombe (University of Glasgow). My task was to photographically document their research into the effects of dietary antioxidants on blue tit nestlings. As well as photographing their experimental methods and techniques, I captured images of the area surrounding the field station in order to build up a picture of the working environment of scientists who are based there. A selection of these images illustrates this short paper.

GLASGOW UNIVERSITY FIELD STATION, LOCH LOMOND

Glasgow University field station was built in 1966, and is situated on the east side of Loch Lomond within the Loch Lomond and the Trossachs National Park. Its remote situation and close proximity to the city of Glasgow makes it a perfect base for scientific fieldwork. Over the years, nearly four hundred nest boxes have been put up in the woods that surround the field station (Ramsay, 2005). Almost all of these are inhabited each year by blue tits, great tits, redstarts or pied flycatchers. Blue tits (*Parus caeruleus*) are the most common inhabitants of the nest-boxes, and are frequently used in experiments because of their abundance and their high resilience to human disturbance (Fig. 1). Various non-invasive experiments have been carried out on the blue-tit population during recent years, most of which looked at the behaviour and ecology of the species. One such study was carried out at the field station in summer 2005 by Dr. Kate Arnold and Stephen Larcombe.

The aim of their experiment was to examine how dietary antioxidants, specifically vitamin E and carotenoids, affect blue tit nestlings as they grow. Studies have shown that the yellow chest and crown plumage of the blue tit plays an important role in mate selection by both sexes, brighter birds being preferred by potential mates (Senar *et al*., 2002). The reason for this preference is unclear; however, there is evidence that the colour is used as a signal of a bird's quality (Hill, 1991). The yellow colour of the feathers derives from a class of compound called carotenoids: pigments, which have antioxidative properties (Partali, 1987). This has led to the theory that the brightness of the chest and crown plumage may be indicative of a bird's internal antioxidant status (Olson and Owens, 1998).

Arnold and Larcombe designed an experiment to test whether or not carotenoids are used as antioxidants, and whether yellow plumage is a signal of an individual's internal antioxidant status, and thus quality. To answer these questions blue tit nestlings were supplemented with carotenoids, vitamin E and a control treatment to test how each affected the plumage brightness and internal oxidative stress levels (Fig. 2). Work is now being carried out in the Glasgow University laboratories to analyze the data collected during the field season, thus no conclusive results are available at this time.

During my time at the field station I was able to follow the research team and photograph various experimental techniques and blue tit behaviours e.g. chick begging behaviour, foraging and incubation (Fig. 3). I photographed the chicks daily, and built up a sequence of photographs documenting their growth patterns, specifically belly feather growth and wing development (Fig. 4).

The research team members were keen naturalists with extensive knowledge of the surrounding area. I was therefore able to glean a great deal of information about the flora and fauna in the vicinity. For example, several bird species, including redstarts (*Phoenicurus phoenicurus*), willow warblers (*Phylloscopus trochilus*), woodcock (*Scolopax rusticola*), pied flycatchers (*Ficedula hypoleuca*), great tits (*Parus major*) and blue tits (*Parus caeruleus*), were seen nesting in the area (Fig. 5). This allowed me to set up a hide a short distance from the nests so that I could photograph these birds in their natural environment without causing any undue disturbance.

THE LOCH LOMOND AND THE TROSSACHS NATIONAL PARK

The Loch Lomond and the Trossachs National Park encompasses fresh water lochs, ancient woodlands, wild glens and vast mountain ranges, and has delighted artists, writers and naturalists for years (Fig. 6). The spectacular landscape is home to a wide variety of flora and fauna, which attract visitors from all over the world, thus making it extremely important for conservation, tourism and scientific study within Scotland.

The national park offers a stronghold for many nationally and internationally important species. Two species that are considered iconic to the park are the red squirrel (*Sciurus vulgaris*) and the capercaillie (*Tetrao urogallus*), both of which are listed as priority species for conservation efforts within the UK.

Loch Lomond itself has more species of freshwater fish than any other Scottish loch (Maitland and Adams, 2005). Amongst them is the powan (*Coregonus lavaretus*), a rare species that is found in only one other loch in Scotland (Scott,1998). In a recent survey of national nature reserves within the UK, Loch Lomond was identified as being of outstanding importance for fish (Lyle and Maitland, 1994). Loch lomondside, the area surrounding the loch, is a veritable paradise for botanists, with a quarter of the UK's 2,000 flowering plants and ferns found there (Tippett, 1974).

Figure 1 Adult blue tit

Figure 2 Feeding a chick with an experimental treatment

Figure 3 Blue tit nestling begging behaviour

Figure 4 Blue tit nestling bellies, 6-14 days after hatching, showing development of feather patterns and coloration

Figure 6 Loch Lomond at dusk

Figure 5 Redstart female, about to feed her you

This botanical species richness stems from the geographical position and the topographical variety of the land (Tippett, 1974).

There are over 200 species of bird found on and around Loch Lomond, making it a haven for birdwatchers and ornithologists. Although mostly elusive, a large assortment of mammals inhabits Loch lomondside, some of which are deemed endangered within the UK. For example, the Scottish wildcat (*Felis sylvestris grampia*), which is the UK's only surviving native cat. Being nocturnal and extremely shy, the wildcat is very rarely seen: however, populations are known to exist within the national park. Another common but rarely seen mammal is the otter (*Lutra lutra*) (McCafferty, 2005).

A multitude of factors makes the Loch Lomond and the Trossachs National Park of vital importance to Scotland. The richness of flora and fauna in the area, along with its outstanding natural beauty, makes it well deserved of its status as a national park. As long as this status is upheld and respected by this and future generations, people will be granted the opportunity to experience for themselves the delights that the area has to offer for years to come.

REFERENCES

Hill, G.E. (1991). Plumage coloration is a sexually selected indicator of male quality. *Nature* **350,** 337 - 339.

Lyle, A.A. and Maitland, P.S. (1994). The importance of Loch Lomond National Nature Reserve for fish. *Hydrobiologia* **290,** 103-104.

Maitland, P.S. and Adams, C.E. (2005). The aquatic fauna of Loch Lomond and the Trossachs: wahat have we got; why is it mportannt; how do we look after its future? *Glasgow Naturalist* **24(3),** 24-28.

McCafferty, D.J. (2005). Ecology and conservation of otters (*Lutra lutra*) in Loch Lomond and the Trossachs National Park. *Glasgow Naturalis.* **24(3),** 29-35.

Olson, V.A. and Owens, I.P.F. (1998). Costly sexual signals: are carotenoids rare, risky or required? *Trends in Ecology and Evolution* **13,** 510 – 514.

Partali, V., Liaaen-Jensen, S., Slagsvold, T. and Lifjeld, J.T. (1987). Carotenoids in food chain studies. 2. The food chain of *Parus* spp. monitored by carotenoid analysis. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology* **87(4),** 885 - 888.

Ramsay, S.L. (2005). Studying nutrition and reproduction of nestbox-breeding birds within Loch Lomond National Park. *Glasgow Naturalist* **24(3),** 47-50.

Scott, M.P. (1998). The ecology and behavior of burying beetles. *Annual Review of Entomology* **43,** 595-618.

Senar, J.C., Figuerola, J. and Pascual, J. (2002). Brighter yellow blue tits make better parents. *Proceedings of the Royal Society of London B.* **269,** 257-261.

Tippett, R. (1974). *A natural history of Loch Lomond.* University of Glasgow Press, Glasgow.

The Glasgow Naturalist Volume 24 Part 3 Pages 56-59 (2005).

FULL PAPER

IN COLD BLOOD: TALES OF A HERPETOLOGIST

J.R. Downie

Division of Environmental and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow G12 9QQ

INTRODUCTION

I got into herpetology by accident. I started as a chick embryologist, working on morphogenetic movements. The advantage of the chick embryo is that it is available all year round and is easy to work on in the laboratory. The disadvantage of the chick embryo is that it is available all year round in this country and gives you no good reason for fieldwork in interesting places. As it happened, I'd developed an interest in teaching reproductive strategies and adaptations in the vertebrates, and this interest led both to research and exotic fieldwork in two main fields:

- temperature-dependent sex determination in marine turtles.
- reproductive ecology of frogs.

These two topics form the main content of this scientific reminiscence. They emphasise the importance, to me, of the links between teaching and research in higher education. Governments tend to feel that research is an expensive activity that can be entirely separated from teaching, and, of course, it is possible to be an effective university teacher without doing research. But to me, this ignores the excellent opportunities for synergy between research and teaching i.e. teaching new fields often opens up new research interests; and for students, there are great advantages, especially in terms of project work, from learning with active researchers.

Much of the work I've been able to do in this area has been made possible by staff-student expeditions. I first went on a Zoological expedition as an undergraduate (Ron Dobson was one of the leaders), then again on the staff in the early 70's. But GU Exploration Society then folded and it was not until 1988-89 that we were able to get it going again. Now we run as many as 9 expeditions each year, all as staff-student collaborations: they involve a lot of hard work in fund-raising, but provide students with excellent experiences, not only of the location visited, and the scientific work possible there, but also of fund raising, a very necessary part of career development these days for any aspiring scientists. I'm glad to acknowledge the role of GNHS through the BLB Bequest in supporting many of these expeditions and thereby in assisting the development of so many young people as natural historians of the future.

TEMPERATURE-DEPENDENT SEX DETERMINATION: THE CURIOUS CASE OF MARINE TURTLES

In an early attempt to understand sex determination, Aristotle reckoned that sex was determined by heat: either by the weather or by passion. The hotter, the more likely the offspring was to be male. Aristotle counselled old men that if they wanted male children, they should have intercourse in the summer, since the heat of their passion would at their age be inadequate on its own! After the discovery of sex chromosomes in the late 19th century, the idea that sex could be determined by an environmental influence like temperature fell out of favour. However, in the 1960's, reports began to appear that temperature determined sex in reptiles. We now know that environmental signals of several kinds determine or influence sex in a wide range of animal species, and even have a general theory, due to Charnov and Bull (1977), explaining why i.e. if offspring are to enter a patchy and unpredictable environment where their success, according to the condition of that environment, can vary depending on whether they are male or female, it is adaptive to use environmental signals to choose sex. This particularly occurs where the sexes are strongly dimorphic in size and the resources available in the environment strongly determine growth. For example, if successful males are large, but the environment does not support growth to a large size, then it can be better for an individual to choose to be female, since a female will generally have reproductive success, irrespective of size, but a small male may have none.

Environmental sex determination, with temperature as the best understood signal, is common in reptiles and universal in the marine turtles. Here, sex is determined in the middle third of the incubation period, when eggs are buried in a nest on a sandy beach. At lower temperatures, all develop as males; at higher as females. The 'pivotal' temperature, producing even numbers of males and females, is a narrow band around 29°C for all species. It is not clear that marine turtles fit Charnov and Bull's theory, since marine turtles become mature 20 or more years after hatching: how, therefore, can the environmental signal of beach temperature, 20 years earlier, determine differential fitness as a male or female in the oceans, after 20 years of growth?

We may not understand why marine turtles use temperature-dependent sex determination (TSD), but we are beginning to be concerned by the consequences. All marine turtle species are classed as endangered, some critically. They therefore have high conservation status. There are many threats to turtle survival:

- Egg and hatchling predation
- Beach development
- Adult turtle slaughter – for meat, or accidentally as by-catch
- Disease

A new threat to their survival, related to TSD is climate change: if global warming is a reality, the future of species using temperature to determine sex may be bleak, since eventually all offspring could be the same sex. A possible

way out is by the colonisation of beaches in new climatic zones, but this is a slow process in marine turtles, because most show high nesting beach fidelity i.e. turtles hatched on a particular beach return there to breed many years later, and then for the rest of their reproductive life. In addition, it is hard enough to prevent recreational development on beaches where turtles are known to nest: saving other beaches for potential turtle use in the future looks a remote prospect.

The work we have done on marine turtles has had many aspects, but a major focus has been incubation temperature. Our first turtle experiences were in Trinidad in 1989 and 1991 – projects which started off the careers of two of this country's most dynamic turtle biologists, Brendan Godley and Annette Broderick, who both went on to complete PhDs at Glasgow and are now at Exeter. Their major work began on the beaches of North Cyprus where we were invited to go and help the local turtle protection NGO – a weird experience given North Cyprus's status as a non-state. The first North Cyprus expedition was in 1992 and the project has run ever since (now, from Exeter), accumulating an unrivalled long-term data-set on turtle populations and breeding success, for the two species nesting there, greens and loggerheads. More recently, GU has established an additional Cyprus turtle monitoring programme hosted by the RAF base at Akrotiri. And we have returned to the Caribbean with more work in Trinidad, focussing on the north coast; and even more recently, Tobago.

The method we have used to monitor nest temperatures is the temperature data logger known as a "Tinytalk". This is similar in size to a turtle egg, and can be inserted into a nest at the time of laying. It measures temperature at whatever interval you want right through the incubation period and is recovered at hatching to download its information.

Loggerheads (*Caretta caretta*) are smaller than greens (*Chelonia mydas*) and dig shallower nests (bottom of nest 55 cm compared to 90 cm for greens). One result of this is that the temperature within a loggerhead nest shows considerable daily fluctuation, since it is highly subject to daily solar heating, then to night-time cooling. This effect is greatest for eggs closest to the sand surface. Greens, deeper in the sand, show little daily fluctuation in temperature (Kaska *et al.*, 1998).

For greens at Alagadi beach, north Cyprus, a data logger study of 18 nests from 1995-1998 showed middle third mean temperatures of 29.7°C or above for all nests. The pivotal temperature for greens is reckoned to be 29.2°C, and our calculations, partly confirmed by examining the gonads of embryos which did not survive till hatching, were that at least 85% of hatchling green turtles from Alagadi were female during the period 1994-1998 (Broderick *et al.*, 2000).

A very similar overall result was obtained for loggerheads. From 23 nests recorded 1993-1999, middle-third incubation temperatures ranged form 29.3°C to 33.2°C, i.e. all were above the pivotal temperature of about 29°C. Again, hatchling sex ratios were estimated to be highly female biased (Godley *et al.*, 2001).

In general, studies from the eastern Mediterranean, which contains most of the marine turtle nesting beaches remaining in that sea, show a series of very hot dry summers with heavily female skewed hatchling sex ratios. It takes about 25 years till turtles begin to breed, so it is not known what effect this sex imbalance will have, but it is generally interpreted as a poor look-out for the future.

Our other main study site has been Trinidad in the West Indies, where the main nesting species is the leatherback (*Dermochelys coriacea*). Nesting beaches are located along the east and north coasts, with some of the north coast beaches being relatively inaccessible to people because of the lack of a road between the villages of Blanchisseuse and Matelot. Since the initial work we did in 1989 and 1991, the Trinidad Government has supported the establishment of local turtle protection groups who are trained to guide visitors, who purchase permits, on the nesting beaches. This excellent scheme has not only provided income to villagers and protection for turtles but has also generated the potential for data collection on the turtle populations. Our more recent work, supported by a DEFRA Darwin Initiative grant, has concentrated on the remoter north coast beaches. These turn out to be much more important for leatherbacks than used to be thought: indeed, it looks as if turtles have only recently begun to use these beaches in substantial numbers (Livingstone & Downie, unpublished observations).

Datalogger records on the north coast reveal middle third temperatures generally below the pivotal temperature, creating a probable male bias. We think that this is weather related: the main part of the nesting season falls in the rainy season, which has been particularly wet over the period of our study: the combination of cloudy skies and cool rainfall has produced relatively low temperatures over much of the nesting period.

A feature only recently thought about for turtle nests is metabolic heating. Turtles are essentially ectothermic i.e. they do not generate substantial heat from their metabolic activities, and therefore have body temperatures very similar to the surrounding sea water – hence the frequent term for reptiles: cold-blooded. An exception is adult leatherbacks whose substantial bulk and continuous activity generates enough heat to raise the body temperature a few degrees above their surroundings.

Turtle nests, buried in moist sand, are quite well insulated, and, as the embryos grow, metabolism of the 90-120 embryos generates a substantial amount of heat. We have attempted to measure this, in the three species we've worked on, to discover whether metabolic heat could have an effect on sex ratio. A tricky aspect of this study has been the design of an adequate control. It is not enough simply to measure the temperature of the sand adjacent to a nest and compare it to temperature within the nest, since the physical nature of the fluid-filled eggs could have different thermal properties to moist sand. Our solution was to make false nests filled with water-filled ping-pong balls, which are very similar in size and shape to turtle eggs. The results have shown that mid-nest metabolic heating is significant and measurable, but unlikely to make a difference to the sex ratio in most nests because the heating effect only becomes substantial by the final third of the incubation period, when sex has already been determined.

REPRODUCTIVE ECOLOGY IN TROPICAL FROGS: TADPOLE DEPOSITION SITE SELECTION IN THE TRINIDAD STREAM FROG

Trinidad has about 30 species of frog: not a huge number for the neotropics, but manageable as a group to get to know, and with a fascinating variety of reproductive strategies. We've worked on a good number of these, but I'll concentrate here on the stream frog *Mannophryne trinitatis*. These live in and alongside the small streams of the steep slopes of the Northern Range mountains, and are also found in a slightly different habitat in the Central Range of hills. Stream frogs are Trinidad's only dendrobatid. Dendrobatids are well known for two features: many species have extremely toxic protective skin secretions, and all species show a considerable level of parental care of their offspring, not a feature we generally associate with frogs in the UK. In fact, *Mannophryne* is a non-toxic dendrobatid, which makes our experiments much easier since they involve some handling of the frogs. In *M. trinitatis*, mating occurs on land, probably in damp rock crevices, and the males then guard the eggs (8-13 in number) till they hatch. The tadpoles then attach to his back and he carries them till he finds a suitable body of water to deposit them into. Parental care ceases at this point: the tadpoles forage for food in the water until they metamorphose into juvenile frogs.

In surveying the habitat where these frogs occur, in very abundant numbers, we often saw males transporting tadpoles, but rarely saw tadpoles in the streams, which were often highly populated by a small predatory fish, *Rivulus hartii*. We then accidentally discovered a stream lacking the fish which had a series of pools full of tadpoles, in very large numbers. Given that each *M. trinitatis* male carries a maximum of 13 tadpoles and that the population of frogs close to each pool was less than 10, an obvious deduction from finding 900+ tadpoles in a pool was that males were migrating some distance to deposit their tadpoles in this pool, and that a likely reason for this behaviour was to avoid the predatory fish, *Rivulus*.

These observations set us out on a series of experiments both in the laboratory and in the field, aimed at understanding deposition behaviour in these frogs. A basic technique we have used is to capture tadpole – transporting males and then offer them a choice of artificial pools to deposit their tadpoles into, in an aquarium tank with the bottom covered in damp leaf litter.

In our first set of experiments (Downie *et al.*, 2001), we asked the following questions:

1. What happens when frogs are presented with no pool to deposit their tadpoles into?
   Frogs explored the tank and kept their tadpoles for 4 days on average, before depositing them on the damp leaf litter.
2. Do they prefer to deposit in pools with or without other conspecific tadpoles?
   We found a strong difference here relating to the origins of the frogs, which was quite unexpected. Frogs from the southern slopes of the Northern Range deposited preferentially in pools without other conspecific tadpoles; northern slope frogs made the opposite choice.
3. In depositing tadpoles, do frogs avoid pools containing potentialpredators?
   We used caged predators (fish and freshwater shrimps) for these experiments. Anti-predator avoidance was very strong.
4. What happens when both the available pools contain predators?
   Most of the frogs behaved as if there were no pools, and deposited tadpoles in the leaf litter, though a few deposited in pools containing shrimps, which are less commonly found in *M. trinitatis* habitat than are *Rivulus*.
5. When a suitable pool was available, tadpole deposition occurred quite quickly i.e. after less than one day usually.

Clearly deposition behaviour was strongly influenced by predator presence, but we were intrigued that males eventually deposited their tadpoles on the leaf litter, in the absence of a suitable pool. Did this imply a limitation on transportation behaviour? Our next set of experiments (Downie *et al.*, 2005) investigated this idea.

Limitation on the duration of transportation could be the result of costs to the male frog or to the tadpole. We tested the following:

1. Are male frogs able to feed when transporting tadpoles?
   Guts of transporting males were variably full, but no more so than other males we examined.
2. Is the locomotory ability of male frogs impaired by carrying a load of tadpoles?
   We tested the mean jump length and the number of jumps taken to travel a fixed distance in transporting and non-transporting males, and found no significant difference. Given that an average tadpole load represents 15-20% of the male frog's mass, this is rather a surprising result. Using a video camera this year, we were able to measure jump speed and again found no significant difference (Buchanan, unpublished results).
3. Is the ability of tadpoles to grow to metamorphosis affected by duration of transportation?
   Again, no impairment from longer transportation. Indeed, longer transport seemed to improve growth rate, possibly because it allowed time for gut development.
4. Is there a risk to tadpoles from drying out, the longer they are on the male's back?
   Like a number of other tadpole species where early development occurs on land, *M. trinitatis* tadpoles survive well out of water, as long as conditions are moist (Downie & Smith, 2003). However, conditions on the male's back may not be moist enough and our simulation of longer-term transport in drier conditions suggested that this factor could be a real limitation. We have also occasionally seen transporting frogs in the field dipping their tadpoles into water, without the tadpoles detaching, suggesting that re-hydration is important.

Our overall conclusion was that reduced tadpole survival out of water plus the fact that transporting males are missing out on mating opportunities are the most likely limits on transport duration.

Our most recent experiments have combined field and laboratory work (Jowers & Downie, submitted). In the field study, we set artificial pools at various distances from a predator-infested stream. The main conclusions from the study were:

1. Frogs were willing to migrate as far from the stream as we set out our pools (20+ metres) in order to find a predator-free pool.
2. Although some frogs deposited all their tadpoles in a single pool, it was commoner to distribute them amongst two or more pools.
3. There was some preference for larger over smaller pools, but it did not matter whether the pool simply contained water or, in addition, leaf litter (which acts both as shelter and food).

CONCLUSIONS

In both of the studies I've reported on, we have begun to uncover undiscovered details of the lives of reptiles and amphibians in the tropics. This kind of detailed work is needed if we are to conserve these groups, both of which are in danger from declining populations worldwide, into the future. The sort of work I've described is very labour intensive: patrolling turtle beaches night after night through the nesting season; capturing enough frogs to generate sufficient sample sizes for statistical analysis. It is the kind of work that benefits enormously from student expeditions, where a sizeable team of keen volunteers is available. Without this sort of research, most of which can be quite low-tech, we are in danger of learning too late about the lives and needs of many fascinating species. As well as valuable fieldwork, student expeditions can do excellent education work, especially with local children.

THE FUTURE?

I hope to continue work in the tropics over the next few years, but also hope to develop more herpetological adventures in the UK. We have done a preliminary study of the slow-worm population on Ailsa Craig (Lavery *et al., 2005*), and this would be well worth more detailed work. We are also looking into the over-wintering of a proportion of common frog tadpoles in some kinds of ponds: why does this happen and under what conditions? We are about to begin on a study of a great-crested newt translocation project in the grounds of the old steelworks at Gartcosh: translocation has not been seriously attempted in Scotland before, and the great-crested newt has high conservation status because of its rarity and relatively stringent habitat requirements.

ACKNOWLEDGEMENTS

This paper is the edited text of the Presidential Address delivered to Glasgow Natural History Society in May, 2005. I'd like to thank the many undergraduate and postgraduate students who have contributed to the work described here, but especially Suzanne Livingstone who has worked both on turtles and stream frogs, and helped me partly overcome my technophobic tendencies. I'd also like to acknowledge the funders of this work, especially the Carnegie Trust for the Universities of Scotland, who are generous funders of student expeditions and small-scale staff research; the University of Glasgow; the Blodwen Lloyd Binns Bequest; and the Darwin Initiative.

REFERENCES

Broderick, A.C., Godley, B.J., Reece, S. & Downie, J.R. (2000). Incubation periods and sex ratios of green turtles: highly female biased hatchling production in the eastern Mediterranean. *Marine Ecology Progress Series* 202, 273-281.

Charnov, E.L. & Bull, J. (1977). When is sex environmentally determined? *Nature* 266, 282-3.

Downie, J.R. & Smith, J. (2003). Survival of larval *Leptodactylus fuscus* (Anura: Leptodactylidae) out of water: developmental differences and interspecific comparisons. *Journal of Herpetology* 37, 107-115.

Downie, J.R., Livingstone, S.R. & Cormack, J.R. (2001). Selection of tadpole deposition sites by male Trinidadian stream frogs, *Mannophryne trinitatis* (Dendrobatidae): an example of anti-predator behaviour. *Herpetological Journal* 11, 91-100.

Downie, J.R., Robinson, E., Linklater-McLennan, R.J., Somerville, E. & Kamenos, N. (2005). Are there costs to extended larval transport in the Trinidadian stream frog, *Mannophryne trinitatis* (Dendrobatidae)? *Journal of Natural History* 39,

Godley, B.J., Broderick, A.C., Downie, J.R., Glen, F., Houghton, J.D., Kirkwood, I., Reece, S. & Hays, G.C. (2001). Thermal conditions in nests of loggerhead turtles: further evidence suggesting female skewed sex ratios of hatchling production in the Mediterranean. *Journal of experimental marine biology and ecology* 263, 45-63.

Kaska, Y., Downie, J.R., Tippett, R. & Furness, R.W. (1998). Natural temperature regimes for loggerhead and green turtle nests in the eastern Mediterranean. *Canadian Journal of Zoology* 76, 723-729.

Lavery, C., Downie, J.R. & Livingstone, S.R. (2005). Growth rate of Ailsa Craig slow-worms: prey preference and temperature effects. *Glasgow Naturalist* 24(2), 79-85.

The Glasgow Naturalist Volume 24 Part 3 Pages 60-66 (2005)

SHORT NOTES

(This is the final Short Notes section to include input from Allan Stirling: see his Obituary on pages 65-6)

HEATH PEARLWORT IN LANARKSHIRE

P. Macpherson[1] & J.R. Hawell[2]
"Ben Alder", 15 Lubnaig Road, Glasgow G43 2RY[1]
40 Durban Avenue, East Kilbride G75 9PA[2]

Within the bounds of Lanarkshire (VC 77), in the 19th century Heath Pearlwort (*Sagina subulata*) was recorded from Shettleston, Tollcross and Crossbasket (Hennedy, 1865). Only pre-1930 records were given for it in the *Atlas of the British Flora* (Perring & Walters, 1962). Later in the 20th century it was seen in May 1976 in the Glasgow Necropolis (NS 6065) by a medical student during her lunch break from the adjacent Royal Infirmary, the plant being described as distinctive with its five relatively large petals (Macpherson, 1976). The next sighting was not until the 21st century, when its presence was noted at a track side in Whitelee Forest, west of Ardochrig and south of East Kilbride by one of the authors (JRH) in August 2002 (NS 5944).

In 2003 we undertook a detailed search along the Whitelee Forest tracks (Fig. 1). Deep in a large forest it is difficult to know a precise position, but with the aid of a Geographical Positioning System it was confirmed that the plant was present in the quadrant NS/ 5.4SE (592449 & 599446) and it was found also in three adjacent quadrants 5.4NE (594451), 6.4SW (607449) and 6.4NW (608453, 610455, 619460 & 631463). Again the habitat was track side, particularly on the slightly widened out areas which serve as passing places and in a small quarry. The 1km square 5945 is, in fact, the only Lanarkshire square in 5.4NE and 5944 plus half of 5943 the only Lanarkshire ones in 5.4SE.

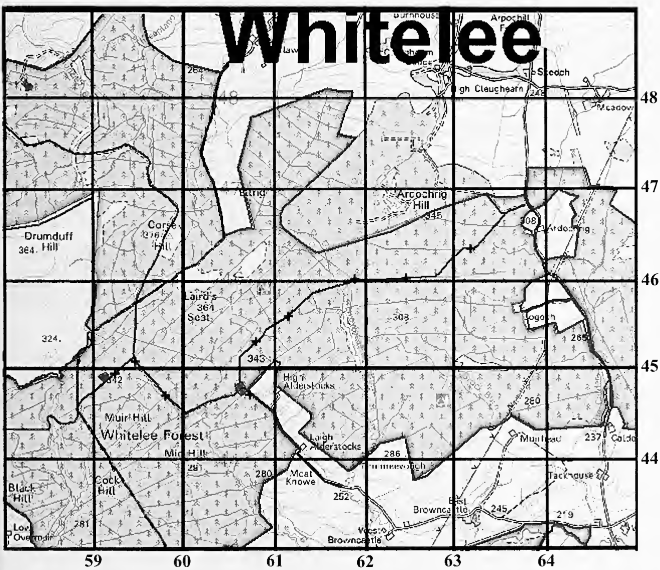


Figure 1. Map of part of Whitelee Forest. The western Lanarkshire boundary is outlined by a black line which extends down from the left inferior part of the W of Whitelee to just west of the 6043 junction. Sites for Heath Pearlwort along the tracks are indicated by + signs.

We have, therefore, been able to increase the quadrant records for the plant from one to five and from one to nine sites. When not in flower it is difficult to be sure of the plant's identity. Some of the locations are at the side of the original roadway constructed when the area was afforested about 30 years ago, but others are in relation to a new track made in the 2000-2001 period.

There is no way of knowing when this Lanarkshire rarity first colonised the area, but it has obviously extended its range considerably in the past two years.

Acknowledgements
In 1976 a specimen was confirmed by R. Mackechnie and one from 2002 by P.M. Benoit. We are indebted to Jim Smalls, Community and Environment Ranger, Forestry Commission Scotland for transporting us into the depths of Whitelee Forest, and for providing information and detailed maps of the area. The map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office: Forestry Commission DG272388.2001.

References
Hennedy, R. (1865). *The Clydesdale Flora; a Description of the Flowering Plants and Ferns of the Clyde District.* Glasgow.
Perring, F.H. & Walters, S.M. (1962). *Atlas of the British Flora*, Thomas Nelson & Sons, London.
Macpherson, ELSL (1976). *Sagina subulata*. *Glasgow Naturalist* 19,339.

SKIMMIA JAPONICA AT CADDER

P. Macpherson[1] & E.J. Clement[2]
"Ben Alder", 15 Lubnaig Road, Glasgow G43 2RY[1]
54 Anglesey Road, Alverstoke, Gosport, Hants PO12 2E[2]

In April 2003 a plant subsequently identified (EJC) as *Skimmia japonica* Thunb. (Rutaceae) was seen in flower in a wood at Cadder, Lanarkshire (VC 77)—NS6172. The laurel-like evergreen leaves are only slightly aromatic, but the gland-dotted surface (translucent to light as in *Hypericum* spp.) separate it from most plants with similar foliage. As far as we are aware, there is only one other record from the wild in Britain "as a garden escape, south side of Brading Down (Wight)" (Clement & Foster, 1994). It was found by E.C. Wallace in a thicket during 1953, *det.* JE Lousley, the voucher being in *RNG* (Univ. Reading). It is unmentioned by Pope *et al.* (2003).

A return visit was paid to Cadder in March 2004 to assess the status. It had presumably been grown at the edge of the long abandoned garden of a ruined house and has spread into the adjacent wood. There are two main patches on either side of a rough track. Each is roughly oval and they are about 8_ apart. One is 7_ x 5_ and the one in the wood 10_ x 4_. They more-or-less form ground cover, being nowhere higher than 18_. In addition, there has been appreciable suckering, with at least three satellites 5_ from any other part. In view of this, it is probable that the two larger colonies are connected underground below the track. The main plant associates are Bramble (*Rubus fruticosus*), Common Nettle (*Urtica dioica*), Elder (*Sambucus nigra*) and Male-fern (*Dryopteris filix-mas*). Further into the wood there is Rhododendron (*Rhododendron ponticum*).

This alien plant in Britain is native in Sakhalin, Japan, Taiwan, Philippines (Luzon) and other smaller islands. It is interesting that the two "in the wild" British records are so far apart. Female plants usually fruit well, but the bright red berries are apparently not relished by birds. Voucher specimens have been preserved in Herb PM & EJC.

References
Clement, E.J. & Foster, M.C. (1994). *Alien Plants of the British Isles.* Botanical Society of the British Isles, London.
Pope, C., Snow, L., & Allan, D. (2003). *The Isle of Wight flora.* Dovecot Press, Wimborne.

WATER FERN IN LANARKSHIRE (VC 77)

P. Macpherson[1] & A. McG. Stirling[2]
"Ben Alder", 15 Lubnaig Road, Glasgow G43 2RY[1]
17 Austen Road, Jordanhill, Glasgow G13 1SJ[2]

In 2002 Water Fern (*Azolla filiculoides*) was seen by Eddie McGuire and Caroline Walker in the most southerly of the ponds which lie in the South Haugh, the low ground between Hamilton and the Avon Water (NS 733553). When assessed in the autumn there were only a few tiny clumps at the pond edge in two of the little baylets. (Fig. 1).

In the *New Atlas of the Flora of Great Britain and Ireland* (Preston *et al.* 2002) there are West of Scotland records for Ayrshire (VC 75) and the Clyde Isles (VC 100). Stace *et al.* (2003) also state that the plant has been recorded twice before in the area, but give Dunbartonshire (VC 99) and not Clyde Isles. In addition, the latter give previous records for Mid Lothian (VC 83), West Lothian (VC 84) and Fife and Kinross (VC 85).

In 1993 the plant was recorded by Tony Church from a pond in Merkland wood, north of Brodick (VC 100), but not seen in subsequent years. The Ayrshire record relates to its occurrence in 1996 in a lake in the Coodham Estate near Symington, where it was seen by John Blane and a Scottish Wildlife Trust Survey Team. In 2000 Keith and Susan Futter saw it in the Forth and Clyde Canal. In September of that year it grew in such profusion between Old Kilpatrick and Dalmuir, Dunbartonshire, that it almost completely covered the surface over a distance of 2.5km. Despite the colony being so extensive and the fact that reproductive bodies (sporocarps) were produced in quantity, it did not survive the winter. Details of the occurrence were exhibited and close-up photographs of the sporocarps shown at the Scottish Annual Meeting of the Botanical Society of the British Isles in November 2000 (Rutherford & Stirling, 2001).

In order to ascertain if the Lanarkshire plant had regenerated after the winter, a further visit was paid in early September 2003. From 100 meters distance one could see that it had not only survived, but had expanded considerably (Fig. 2: printed on the back cover of *Glasgow Naturalist* 24(2), 2004). An irregular colony of approximately 20 x 10 meters was floating about 15 meters from the bank. In addition, there were numerous satellites. Whereas the fronds seen in 2002 had been green, it was already in its reddish-brown

autumnal colouring. The Lanarkshire record is the only one in the West of Scotland where a colony is known to have over- wintered.

Water fern is sold as an ornamental plant in garden centres, but as we have not seen it in any of those in the Clyde Valley, it probably arrived as a migrant on the foot or feather of a bird. We have been asked if the Water Fern is eaten by wildfowl. Certainly not by the geese which frequented the pond throughout the summer of 2003! – nor in the Forth and Clyde Canal as far as we know. Although each plant is so tiny, the growth of the main colony was so compact that it completely damped down the little ripples generated when wading in to obtain a close–up photograph.

With the view of addressing the threats posed by invasive alien plants, a document has recently been circulated to interested parties by the Scottish Executive, inviting comments as to whether or not a number of extra species should be added to Schedule 9 Part II of the Wildlife and Countryside Act 1981. The list includes Water Fern. In the event of a decision to have it included, Water Fern- each plant of which is minute- would be in the same category as Japanese Knotweed (*Fallopia japonica*)!

Fig. 1. Individual plants of Water Fern in 2002.

Acknowledgements
We are grateful to Alison Rutherford and Angus Hannah for supplying relevant information.

References

Preston, C.D., Pearman, D.A. & Dines, T.D. (2002). *New Atlas of the Flora of Great Britain and Ireland.* Oxford University Press.
Rutherford, A. & Stirling, A. McG. (2001). *Azolla filiculoides* (Water Fern) in the Forth and Clyde Canal. *BSBI Scottish Newsletter* 23, 12.
Stace, C.A., Ellis, R.G., Kent, DH and McCosh, DJ (2003). *Vice-County Census Catalogue of the Vascular Plants of Great Britain* etc. Botanical Society of the British Isles.

GREY SQUIRRELS AND PINE MARTENS AT EAST LOCH LOMONDSIDE

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 0DX.

Loch Lomondside would appear to be one of the first parts of Scotland where Pine Martens *Martes martes* spreading from the north-west highlands have come into direct contact with a well entrenched population of the introduced North American Grey Squirrel *Sciurus carolinensis*. This has raised the possibility that the presence of this agile, tree-climbing carnivore might prove an effective check on Grey Squirrel numbers.

The writer's observations on Grey Squirrels made during the 1990s in the woodlands bordering the east side of Loch Lomond would seem to suggest that their numbers were indeed falling following the establishment of Pine Martens in the district (Mitchell, 2001, p. 173). Since then, confirmation of such a decline has been forthcoming from up to a dozen other observers who live and/or work in the area. Without exception all had the same story to tell, that in their own particular patch the once familiar Grey Squirrel had either disappeared or become extremely scarce. Conversely, on the off-shore islands – where as yet no sightings of martens have been reported – the squirrel population has shown little change (M.A. Bates *pers comm.*).

Positive evidence that Pine Martens were preying on Grey Squirrels was finally obtained in early April 2004, when the gamekeeper to Buchanan Castle Estate near Drymen witnessed a marten closely pursing a squirrel through the tree tops before catching it and making a kill. The marten then descended with its quarry before dragging it down a hole amongst the roots of a tree (A. Cowan, *pers comm.*).

Reference

Mitchell, J. (2001). *Loch Lomondside.* New Naturalist. No. 88. Harper Collins, London.

SUCCESSFUL TRANSLOCATION OF GRASS VETCHLING *LATHYRUS NISSOLIA* IN DUMBARTON FROM A SITE OF DEVELOPMENT TO AN AREA OF SEMI-NATURAL GREENSPACE

Keith Futter
81 Oxhill Place, Dumbarton G82 4EX

In July 1990 the Scottish Wildlife Trust (SWT) Dumbarton habitat survey team located a previously undocumented colony of grass vetchling *Lathyrus nissolia* growing at the site of a former quarry at Dalmonach, Vale of Leven (NS397805) near Jamestown, West Dunbartonshire (Futter, 1990). The colony was flourishing in an area of wet grassland and was a locally abundant plant in the field where it was growing. Further detailed surveys carried out by the SWT team did not locate the species at any other site within the Leven Valley or Dunbartonshire (SWT 1992).

Grass vetchling is a native plant with a population stronghold in southern England although it is generally uncommon and declining (Berks, Bucks & Oxon Wildlife Trust, 2004). In Scotland it is a rare plant and because of this it has been assumed that plants in Scotland are introductions (Perring & Walters, 1990). How grass vetchling became established at Dalmonach is unknown but judging from the size of the colony it must have been present for many years.

New housing developments have been consuming green spaces in Dumbarton and the Vale of Leven at a rapid rate since the mid 1990's. The Jamestown area in particular has attracted developers and several new estates have sprung up in recent years. With the possible development of Dalmonach for housing and the destruction of the site it was decided that a rescue attempt would be made to safeguard the grass vetchling.

In 1994 and 1995 seed was collected from the threatened site. The collection of seed was a collaborative project between the Dumbarton District Council Leven Valley Initiative Ranger Service, proposed developers of the site and myself as the then Nature Conservation Officer for the River Valleys Strategy (Scottish Natural Heritage/ Strathclyde Regional Council). Grass vetchling is an annual and therefore seed would be a more effective way to store and transfer plant material to another suitable site.

An investigation of similar grassland sites to the donor site revealed that the semi-natural grassland at the Brucehill Cliff, Dumbarton (NS384752) was regarded as the most suitable to host the grass vetchling. The location was unlikely to be developed as it was a former landfill site and was likely to be conserved for wildlife as a proposed Local Nature Reserve and maintained as greenspace for the community.

The collected seed of the grass vetchling was sown at one location at the new site directly onto an area of wet, marshy grassland without disturbing the habitat and plant life present. The distance between the donor site and receiver site was 6km and both sites occurred within the same drainage catchment area of the River Leven. Seed was also donated to the SWT Urban Wildlife, Jupiter Project at Grangemouth.

Although there is evidence that many translocation attempts are failures (Pearman & Walker, 2004) this particular grass vetchling translocation project has been successful although widespread colonisation has not occurred. Monitoring of the receiver site from 1997-2004 revealed that a small colony of grass vetchling has become established at the receiver site without affecting other plant life in the vicinity. In July 2004 only nine flowering plants were found however there could be more plants, as grass vetchling is a notoriously difficult plant to locate when not in flower. The donor site at Dalmonach, as predicted, was totally destroyed in late 2003 and early 2004 for the development of housing.

References

Berkshire, Buckinghamshire, Oxfordshire Wildlife Trust (2004). *Whitecross Green Wood Nature Reserve leaflet.*

Futter, K. (1990) *A Habitat Survey of the Leven Valley, Dumbarton District*, (unpublished Scottish Wildlife Trust report)

Pearman, D. & Walker, K. (2004) Comment - Rare plant introductions in the UK: Creative Conservation or wildflower gardening. *British Wildlife* **15** (3), 174-182.

Perring F.H. & Walters S.M. (1990) *Atlas of the British Flora.* BSBI

Scottish Wildlife Trust (1992). *Leven Valley Dumbarton District Habitat Survey.* Leven Valley Initiative (Dumbarton District Council, Strathclyde Regional Council, Scottish Natural Heritage), unpublished report.

A ROE DEER *(CAPREOLUS CAPREOLUS L.)* ON GREAT CUMBRAE ISLAND

P.G. Moore

University Marine Biological Station, Millport, Isle of Cumbrae, KA28 0EG

During the last week of July 2004, at least six independent sightings have been made by trustworthy observers (farmers) of a young roebuck on Gt Cumbrae Island in the Firth of Clyde. I have also seen photographs of the animal taken by Mr. David Stevenson that completely substantiate the record.

Deer can certainly swim well. Moore (2002) counted them as being among the naiads of mammals (along with hippopotamuses and elephants). The shortest crossing to Gt Cumbrae Island from the adjacent mainland, where roe deer are abundant, is about 1 km. Even where roe deer are abundant, the general public is often unaware of them, due to their secretive habits and activity mostly being confirmed to less social hours (dawn and dusk).

This individual looks likely to lead a lonely, if well-fed, life. There are no other deer of any species on Gt Cumbrae Island. In 1966, or thereabouts, a single red deer stag was found dead on the shore of Gt Cumbrae Island (it had been shot through the stomach) (Shillaker & Gibson, 1974). There is mention in the book by Campbell (1975) of local memory of roe deer on Gt Cumbrae in the 1920s. There is also supposed to have been a roe deer sighted by one of the local farmers between that date and now (Mr. M. McIntyre, *pers comm.*) but this seems to be the first completely substantiated record of roe deer on Gt Cumbrae Island.

References

Campbell, J.R.D. (1975). *Millport and the Cumbraes: a history and guide.* Cunninghame District Council, Irvine, 127pp.

Moore, P.G. (2002). Mammals in intertidal and maritime ecosystems: interactions, impacts and implications. *Oceanography and Marine Biology: an Annual Review* **40**, 491-608.

Shillaker, R.O. & Gibson, J.A. (1974). Notes on the mammals of the Cumbrae islands. *The Western Naturalist* **3**, 23-30.

FLATWORM (PLATYHELMINTHES, TRICLADIDA) RECORDS FROM COLONSAY, INCLUDING TWO SPECIES NEW TO SCOTLAND.

E.G. Hancock
Zoology Museum, Graham Kerr Building,
University of Glasgow, Glasgow, G12 8QQ.

On the 24th August 2005 a healthy population of the New Zealand flatworm, *Arthurdendyus triangulatus* (Dendy), was observed under stones and pieces of wood within the formal gardens of Colonsay House. The New Zealand flatworm is a well known species, indeed has achieved the status of notoriety as a potential pest (e.g. Jones & Boag, 2001), and is widespread in northern Britain. It has been found recently on Coll by Brian Boag but not recorded before now from Colonsay (Hugh Jones, pers. comm.).

A closer look at the surrounding wooded policies of the estate revealed the presence of two other alien terrestrial flatworms. One example of *Kontikia andersoni* Jones and two *Kontikia ventrolineata* (Dendy) were under pieces of wood near the glasshouses. The first of these species is of unknown native origin but most likely Australia or New Zealand; the latter is from Australia (Jones, 2005). Four more specimens of *K. ventrolineata* were discovered by searching under the bark of felled spruce trees. Both *Kontikia* species are previously unrecorded from Scotland. There are only a few records indicating their presence in England and the Irish Republic. Field identification was aided by a recent article with excellent colour photographs (Jones, 2005). However, the *K. ventrolineata* specimens had a slightly bluish tinge to the dorsal stripes and could potentially be confused with *Australopacifica coxii* (Fletcher & Hamilton) that is characterised by blue stripes. Consequently, examples were sent to Hugh Jones for confirmation.

The flatworms are not the only Antipodean creatures that are thriving on Colonsay. The most prominent non-native invertebrate in the Colonsay estate woods is the landhopper, *Arcitalitrus dorrieni* Hunt (Crustacea, Amphipoda), thought to be native to Australia. They are so abundant within the decomposing leaves as to make the ground surface appear to move when the litter layer is disturbed. This animal is a relative of the familiar shoreline sandhoppers but is typically associated with dry leaf litter. It was first discovered and described from the Scilly Isles in 1925 and is now widespread in southwest England, with isolated colonies also in southern Ireland and Colonsay (Friend & Richardson, 1986). The landhopper was not recorded from Colonsay House until about 1976 although the gardens were landscaped in the 1930s. This process incorporated exotic plants such as tree ferns, eucaplypts and *Crinodendron*. It is possible that alien invertebrates were introduced to Colonsay at this time.

The first arrival of flatworms and landhoppers on the island is likely to be linked to the period of greatest activity of plant movement. Material would have been imported directly from the southern hemisphere or translocated from other gardens within Britain or Europe on one or more occasions. It would be interesting in relation to Colonsay to consult records of importation and plant movements to, from or between various other gardens during the twentieth century. The New Zealand flatworm and the *Kontikia* species may have been resident on Colonsay undetected for a considerable length of time.

Currently there is an interest in alien wildlife that is producing more records of non-native plants and animals in general, partly stimulated by the Glasgow Natural History Society conference 'Alien Species – Friends or Foes' in 2001 (see Supplement to volume 23). The specimens of *Kontikia* have been added to the Hunterian Museum (Zoology) collections (accession numbers: 127244, 127245) and the records with photographs can be viewed on <http://www.huntsearch.gla.ac.uk/>.

Acknowledgement
Dr Hugh Jones (Scientific Associate of the Natural History Museum, London) kindly confirmed the identification of *Kontikia ventrolineata.*

References

Friend, J.A. & A.M.M. Richardson (1986). Biology of terrestrial Amphipods. *Annual Review of Entomology* **31**, 25-48.
Jones, H. (2005). Identification, British land flatworms. *British Wildlife* **16**(3), 189-194.
Jones, H. & B. Boag (2001). The invasion of New Zealand flatworms. *Glasgow Naturalist* **23** (supplement) 77-83.

THE SLENDER BRINDLE IN WEST CENTRAL SCOTLAND

John Knowler
3 Balfleurs Street, Milngavie G62 8HW

The Slender Brindle (*Apamea scolopacina*) is a moth of woodland rides and clearings where its larvae feed on woodland grasses. It is chiefly found in England and Wales but extends to Dumfries and Galloway (Waring et al., 2003).

Two adult males caught in a Skinner light trap which I ran at the Visitor Centre of Mugdock Country Park Centre (NS 548779) on 30th July 2004 were apparently the first records for central Scotland. However, it has since become apparent that the species is well established in the area and I have recorded it at three separate locations in 2005. Fourteen adults were caught in a Skinner light trap run at Kyber Cottage at the end of Mugdock Wood (NS 540772) on 25th July 2005. Two more were caught in a Skinner Trap at an Introduction to Moth Trapping and Identification run by Butterfly Conservation at the David Marshall Lodge, Aberfoyle (NN 520014) on 29th July,2005 and another was caught at the Visitor Centre of Mugdock Country Park Centre on 9th August, 2005.

Reference

Waring, P., Townsend, M. and Lewington, R. (2003). *Field Guide to the Moths of Great Britain and Ireland*, British Wildlife Publishing.

The Glasgow Naturalist Volume 24 Part 3 Pages 65-66 (2005).

OBITUARY

Allan McGregor Stirling - 1924-2004

Allan Stirling (Fig. 1) joined The Andersonian Naturalists of Glasgow (as the Glasgow Natural History Society was then called) in 1951 and attended the 100^{th} and 150^{th} anniversary celebrations in 1951 and 2001 respectively.

He was elected a member of Council in 1955, but resigned a year later on obtaining a post in Chester. On his return to Glasgow he re-joined the Society in 1961 and was appointed Honorary Treasurer in 1963. He served in this office for nine years before becoming Convenor of Botany 1972-73. His attributes being appreciated, he was elected President 1973-75. In 1974 he took on also the duties of Assistant Secretary (Excursions) and continued in this post until 1982. In 1979 he became a member of the Editorial Board and Compiler of Short Notes for the *Glasgow Naturalist*, a post he held until his death. He was a Vice-President from 1984-86 and a Councillor 1987-89. He served, therefore, continuously as an office bearer for over 40 years. In recognition of his contribution, he was elected an Honorary Member of the Society in 1995. In addition to holding formal posts, he contributed to the Society in other ways: leading Field Meetings; giving Formal Talks; tabling many interesting exhibits and, being an excellent photographer, was a frequent contributor to the Members' Slide Night Presentations.

Allan Stirling was born in Mosspark, Glasgow and educated at Jordanhill School (now College). His interest in wild plants was kindled when, as a student at the West of Scotland Agricultural College, he was sent for practical experience to work on a hill farm on the west side of Loch Lomond. As part of his course, he was expected to identify 100 different plants growing on the farm. Initially, he took the National Diplomas in Agriculture and Dairying and after War and National Service in the R.A.O.C., obtained the General Agriculture Diploma in 1949. After qualifying he worked in the Bacteriology Department of the West of Scotland Agricultural College, engaged in Farm Advisory work and part-time lecturing. He then became a cheese and butter grader, working for a time in Chester, before returning north to become Assistant Manager of a Milk Powder Factory of the Scottish Milk Marketing Board. In 1962 he was appointed Technical Officer of Creamery Production at the head office in Glasgow.

In the 1950s he teamed up with Alfred Slack and by camping out overnight, they were able to explore some of the more mountainous areas of Scotland, acquiring records for the *Atlas of the British Flora* (Perring & Walters, 1962). He developed an interest in hawkweeds and went on excursions with Archie Kenneth. They made a significant contribution to the study of the genus in Scotland. Initially just collecting, but subsequently became knowledgeable. Specimens presented to the Cambridge Botanic Garden about 1960 formed a valuable addition to their collection. A summary of their findings appeared in *Watsonia* (Stirling & Kenneth, 1970). Working with Anne Sleep on the 'false serpentine spleenwort' *Asplenium adiantum-nigrum* ssp. *silesiacum*, he visited serpentine outcrops all over Scotland, taking many tiny glass tubes and preservative for pieces of frond. Having learned of the re-finding of *Polystichum* x

Fig 1 Allan in action examining *Crassula aquatica* (Photograph: Peter Macpherson)

illyricum (*P. aculeatum* x *P. lonchitis*) in Ireland in 1972, he surmised that a likely site would be on the limestone scree at Inchnadamph in Sutherland. Accordingly, he paid a visit in1973 and (with permission from the Nature Conservancy) fronds taken from three plants, which he considered to be likely candidates, were confirmed by Dr Sleep to be the hybrid. Later in the year they both visited the site and discovered 39 plants. The discovery constituted the second British record. With the help of Dick Roberts he became an expert at identifying the polypodies and their hybrids. He had made a study of base-rich areas and with Alison Rutherford found eleven sites for *Polypodium cambricum* in Scotland, and one for the only known site for *P.* x *font-queri*, its hybrid with *P. vulgare*, at Maidenbower Craigs near Dumfries (Rutherford & Stirling, 1973). They also made exploration trips to discover which *Lamiastrum* subspecies were established in central Scotland—the ramping *L. galeobdolon* ssp. *argentatum* or spangled forms of ssp. *montanum*. The resulting information was published in *BSBI News* (Rutherford & Stirling, 1987) and the differentiating features in the *Plant Crib 1998* (Stirling & Rutherford, 1987). In addition, he had a good working knowledge of a number of other critical genera: e.g. brambles, dandelions, roses, willows and sedges.

His experience and dedication were appreciated also by other Societies. He joined the Botanical Society of the British Isles (BSBI) in 1954 and was actively involved with the Society until his death. In particular, he was appointed plant recorder for Dunbartonshire (VC 99) in 1961, transferring to Ayrshire (VC 75) in 1987. In the 1960s-70s he was a member of the Committee for the Study of the Scottish Flora (CSSF), a joint undertaking involving the BSBI and the Botanical Society of Edinburgh (BSE), whose aim was to promote projects in Scotland – e.g. the CSSF instigated recording which culminated in the 1985 publication of *A Map Flora of Mainland Inverness-shire*. Elected a founder member of the BSBI Committee for Scotland in 1977, he became its first Vice-chairman and second Chairman. He served on the committee again from 1986-91. He was joint editor (with Peter Macpherson - PM) of the *BSBI Scottish Newsletter* for Issues 1-26 (1979-2004). In 1993 he gave the formal presentation at the Scottish Annual Meeting (jointly with the GNHS), the subject being the "Flora of the Vice-county Ayrshire".

His knowledge of plants was not limited to Scotland. He botanised in other parts of Great Britain and as co-recorder is credited with the first record for Wales of *Eriophorum gracile* (Slender Cottongrass). Further, he went with the CSSF on their annual field meetings to Scandinavia or elsewhere in Europe and attended foreign meetings led by BSBI members, in particular to south Spain. By taking ivy cuttings from a wide range of sites, he laid the groundwork for the *Hedera* research by Hugh McAllister at Ness Gardens, Liverpool University, which led to the *Hedera* account in *Flora Iberica* (Valcarcel *et al.*, 2003).

He had an interest also in bryophytes (joining the Bryological Society in 1963) and became acknowledged by fellow bryologists as having 'a good eye' for even the most inconspicuous of species.

He had over 50 publications (ten as co-author with PM). Most were related to the west of Scotland—mainly new native or alien records, distribution of a species or site recording. In particular, he made a significant contribution to the knowledge of the flora of the Loch Lomond National Nature Reserve. In addition he complied with a request from the Botanical Society of Edinburgh to contribute to their "The Botanists' Scotland series" and had published 'A Botanical Sketch of Dunbartonshire' (Stirling, 1978).

He was also interested in freshwater snails, could name most butterflies and birds and had enough geological knowledge to enable him to find plants with a specific requirement.

The Stirling family have donated most of his books, along with his photographic slides and microscope to the Glasgow Art Gallery and Museum. Allan Stirling accumulated an enormous private vascular plant and bryophyte herbarium. Although this collection is predominantly from west and central Scotland, it also includes much material from other parts the British Isles and abroad. *Pteropsida*, *Rubi* and *Hieracia*, three of his particular interests, are very well represented and there is also an appreciable collection of named *Taraxaca*. He has bequeathed this invaluable collection to the Royal Botanic Garden Edinburgh Herbarium. It required two crammed-full carloads to transport the packages! Duplicate material will be returned to Glasgow.

Allan Stirling spanned the period from the 'old school' days (meeting John Lee in the 1950s) to the current era of DNA determinations. He was definitely one of Scotland's best field botanists.

We are grateful for information supplied by John Mitchell, David McCosh and Jim McIntosh.

REFERENCES

Hadley, G. Ed.(1985). *A Map Flora of Inverness-shire*. Botanical Society of Edinburgh & Botanical Society of the British Isles.

Perring, F.H. & Walters, S.M. (1962). *Atlas of the British Flora*, Thomas Nelson & Sons, London.

Rutherford, A. & Stirling, A.McG. (1973). Observations on *Polypodium australe* Fee in Scotland. *Watsonia* **9**, 357-361.

Rutherford, A. & Stirling, A.McG. (1987). Variegated Archangels. *BSBI News* **46**, 9-11.

Stirling, A.McG. (1978). A Botanical Sketch of Dunbartonshire. BSE News **26,** 5-7.

Stirling, A.McG. & Kenneth, A.G. (1970). Notes on the Hawkweeds (*Hieracium* sensu lato)of western Scotland. *Watsonia* **88**, 97-120.

Stirling, A.McG. & Rutherford, A. (1987). *Lamiastrum argentatum / Lamiastrum galeobdolon* subsp. *Montanum 'variegatum'* in *Plant Crib 1998* Eds. Rich, T.C.G. & Jermy, A.C. Botanical Society of the British Isles.

Valcarcel, L.V., McAllister, H.A., Rutherford, A. & Mill, R.R. (2003). *Hedera* in *Flora Iberica Plantas vasculares de la Peninsula Iberica e Islas Baleares*. Vol 10 Ed. Castroviejo, S. Real Jardin Botanico CSIC Madrid.

Peter Macpherson and Alison Rutherford

The Glasgow Naturalist Volume 24 Part 3 Pages 67-74 (2005).

BOOK REVIEWS

Compiled by RUTH H. DOBSON

HISTORY OF LIFE

Richard Cowen

Blackwell Publishing, Oxford, 2004. 4th Edition, 324 pp., softback with many line drawings and a few monochrome photographs. ISBN 1-4051-1756-7. £32.50.

This book was written as a text for students attending the course in *History of Life* given for many years by the author at the University of California, Davis. First published in 1990, revised editions have appeared at five year intervals and this is the latest. The very extensive bibliography is quite up-to-date with numerous references to articles as recent as 2003 and the text, displaying considerable erudition, is readable and almost devoid of typographical and other errors.

The field covered is exceptionally broad. It commences with an account of the geological, climatic and chemical conditions needed to support life and proceeds to discuss its various degrees of organisation from possible signs of photo-synthesis in archaean rocks to the present day fauna and flora. Much information is, of course, dependent on fossil evidence and many examples are given for each level, relationships being almost always expressed in terms of cladistics. A welcome approach is that throughout attempts have been made to reconstruct the probable life-styles of the various groups as evinced by their anatomy and inferred living conditions.

Relevant aspects of plate tectonics and continental drift are explained and reasons for the mass extinctions which led to world-wide changes in the fauna and flora are discussed. The title is slightly misleading in that the emphasis is on the evolution of chordates and the coverage of invertebrates is sparse. Also the plant kingdom receives little attention. One of the strengths of the book is that the author is not dogmatic concerning his views on controversial matters but presents various opinions in an unbiased fashion. At times, however he seems over confident in claiming that certain taxa are derived from known ancestors where, of course, there can by no certainty.

The book ends with recent events and includes a fascinating account of the general devastation inflicted by Man on the environment and the reckless folly and insupportability of this.

An unusual, and light-hearted, feature is the provision of marginal limericks to emphasise particular points. About all one can say of these is –

An erudite don has published a text,
Enhanced by some humorous verses
Though good for a grin,
They're poetically thin,
And I couldn't care less which the worst is.

Ronald M. Dobson

MANAGING SCOTLAND'S ENVIRONMENT

Charles Warren

Edinburgh University Press, Edinburgh, 2002, 410 pp., hardback or softback with numerous black and white photographs, figures and tables. ISBN 0 7486 1312 9 (hardback) £65, 0 7486 1313 7 (softback) £24.99.

Scotland's natural environment is one of the nation's greatest assets. Finding ways to reconcile the conflicting demands of conservation and landscape quality with social and economic development is one of the greatest challenges for the nation. Fortunately, we are also at a time when it is widely recognised that we need to find new approaches to solve these problems and to resolve old conflicts, and this book could not have come at a better time. According to the author's preface, the book arose out of the need for a student textbook on environmental management in Scotland. But it will be of interest to a far greater range of readers than just undergraduates. I am sure that it will become the classic text for all those involved practically and politically in environmental matters in Scotland, or for anyone needing both an informed background to environmental issues as well as a stimulating and thoughtful insight into the future.

The book is sensibly organised into five sections. The first deals with the history of our natural heritage and the political development of environmental policies. There are then chapters on the history and current problems facing each of the main areas of land use, such as forestry, agriculture, water management, and wildlife conservation. A third section deals with the interactions between alternative approaches to the environment, illustrated with controversial issues such as deer management, tourist development and superquarries. This is followed by a more philosophical discussion on how we should view the environment, dealing particularly with sustainability and the precautionary principle. The book concludes with a thoughtful essay on the way forward, stressing the impact of recent concepts of partnerships and community involvement.

Some of the individual areas dealt with in this book have received recent reviews elsewhere, but this book really does achieve its aim of providing an overview of all these issues for Scotland, placing them in an historical context, and considering the way forward. Although it covers some contentious issues, such as land ownership, access rights, and deer management, it always gives a balanced coverage and presents all sides of the argument. As a result, some may disagree with some sections, but there have been rather too many political rants published on some of these issues and it is a huge achievement to present these topics in such an informed, authoritative and sensible manner. The author has a lively writing style and sense of humour, so the text is a pleasure to read and far from a dry textbook. It has many tables and figures which condense a formidable

amount of information, and is also an excellent source of the latest literature on a huge range of environmental issues. Anyone with a serious interest in the future of our environment should read this book.

David C. Houston

SAVANNA LIVES: ANIMAL LIFE AND HUMAN EVOLUTION IN AFRICA.
Staffan Ulfstrand

Oxford University Press, Oxford, 2003, 315pp., hardback with colour photographs, line drawings and figures. ISBN 0 19 850925 1. £18.99

This book, which has been translated from the Swedish, is written by a Zoologist from Uppsala University. The author has a passion for African wildlife, has travelled widely, and this book is a popular account of his personal impressions of African savannas. It starts with a brief general section on the nature of savannas, stressing how they are highly dynamic systems influenced by fire, water and grazing pressure. There then follow a series of chapters each on some of the more spectacular animals to be found there, such as elephants, giraffe, some of the ungulates, hyaena, lion, baboon and chimpanzees, with an essay on the wonders of the Okovango swamps. These Chapters are a mix of recent scientific research together with some good anecdotes from field observations made by the author and others. It is generally successful in giving popular accounts of these animals. It is very obviously based on the author's personal enthusiasms. There is nothing wrong in that. But it does result in rather an unbalanced account, with an obsession with a few large mammals (other animals get little mention). Well over a quarter of the book is devoted to an account of human evolution – on which there are already many excellent popular accounts - and which sits rather uneasily with the other chapters. And some of the sections on evolutionary theory are not well explained and would flummox most non-biologists. It is also irritating in that the source of information is not given, so one is often unsure whether a statement is based on good evidence or just the author's opinion.

David C. Houston

SPAIN: TRAVELLERS' NATURE GUIDE
Teresa Farino and Mike Lockwood

Oxford University Press, 2004, 463 pp., softback with colour photographs, maps and line drawings. ISBN 0-19-850435-7. £16.99.

This is the fourth in the series of Travellers' Nature Guides published by Oxford University Press, those for France, Greece and Britain having been previously reviewed (*Glasgow Naturalist* 24(2) 155-6 2004).

This is an indispensable book for the independent traveller visiting Spain and looking for the best places for natural history. The book starts with an overview giving a general account of the geography, climate, history, habitats, vegetation, wildlife and nature conservation in Spain as a whole. The country is divided into 17 administrative regions, and each section of the book deals with one or more communities. For each region a number of selected sites, not all of which are reserves or national parks, are described. Important plants, birds, mammals, reptiles, amphibians, freshwater fish and insects are mentioned. There are colour photographs of species and habitats and line drawings. The book includes maps showing where the selected sites are within each region, and other more detailed ones for some sites.
I think the writers, both of whom live in Spain, have conjured up an enticing picture of the natural history of the country and have shown that there is a great deal more to be gained from a visit than sun-drenched beaches and high-rise hotels.

Edna Stewart

THE NATIONAL PARKS AND OTHER WILD PLACES OF BRITAIN AND IRELAND
Jonathan Elphick and David Tipling

New Holland, London, 2002, 176 pp., hardback, with many colour photographs, maps, select bibliography, index. ISBN 1-85974-898-8. £24.99.

This is an easily read and well presented book. Each area visited is illustrated with a map and there is a handy quick guide in argument form for each area. Notes on suitable clothing, the best time to visit, the requirement of permits, accommodation and non-natural history related activities are given. Included in the main text is information on birds, wildflowers, maritime and freshwater life, butterflies, moths, insects, geology, archaeology, climate as well as useful information on place-names and their derivation.

This book is suitable for the general reader and is ideal for those planning a holiday. It illustrates the diversity of wild life in Britain and Ireland and is a real "eye-opener".
This book is excellent value for money. However, as is noted, it was written prior to the Loch Lomond National Park coming into being and it is hoped that a chapter on this will be added should there be a second edition.

Margaret M.H. Lyth

SEASHORE
Peter J. Hayward

New Naturalist No. 94, Harper Collins, London, 2004, 288 pp., hardback with 16 colour plates, drawings and diagrams. ISBN 0-00-220030-9. £40.

This Natural History of the Seashore is well presented on high quality paper which shows off the very fine line drawings. Following the introduction, there is a good and full description of the physical and chemical factors which shape and influence the various types of marine habitats that make up our coastal shores. The effect of the lunar cycle on the height of water at any time on the shore and how the tidal currents progress round Britain's coast is well explained, though the picture of the first quarter moon in Figure 1 seems incorrectly shown. The importance of how topography and geology interact with other factors like salinity and temperature is shown to produce the many and varied inshore habitats.

The largest section of the book is devoted to a description of all the major phyla found by the seashore and there are some excellent detailed drawings. We are told that ragworms of both sexes leave the sea floor and swarm in the surface waters to shed eggs and sperm into the sea before dying, and that this happens usually at night and at certain phases of the moon. I'd love to know when. The fascinating detail of the life cycles of the male and female parasitic barnacles *Sacculina carnini* has left me a little confused as the text says the females develop into kentrogon larvae, and the males into trichogon larvae, but the glossary which I went to for further clarification states the opposite – that female larvae are trichogon and male larvae are kentrogon. Having been brought up on Garstang's lovely little ditty about the veliger being a "lively tar" I had assumed that the torsion described applied only to gastropod veligers, so it was instructive to learn that oysters also produce veligers.

Rocky shores, seaweed zonations, sandy shores and fish are dealt with in separate chapters and in each the factors which govern the diversity of species is most interesting and well described.

The final chapter deals with the Changing Seashore. This is a wide ranging discourse on the threats to the habitat by human and natural events and their effects on marine life. All the conservative wastes are discussed, heavy metals, TBT, PCBs, radioisotopes and oil waste, with their effects on various organisms. Algal blooms are well explained as is how the introduction of alien species play their part in the fascination of the diversity of seashore species. Disappointingly, bioluminescence was not mentioned. Climate changes will also result in alterations to the whole environment and the expected rise in sea level, and subsequent erosion in various locations, will contribute to the ever changing seashore.

This book should encourage new generations of marine scientists to investigate further.

Morag Mackinnon

SEASHORE (COLLINS WILD GUIDE)
Ken Preston-Mafham

Harper Collins, London, 2004, 256 pp., softback with waterproof cover and 240 colour photographs. ISBN 0-00-716071-2. £8.99.

This is a useful pocket sized field guide for the beginner with sections covering examples of most of the wild life to be encountered on the sea-shore. The section on birds is brief as these are described in another book. Each species is illustrated by a colour photograph of it in its normal habitat when alive. The photographs are of a high quality. Each entry has a useful identification fact file with a guide to "lookalikes". There is excellent cross-referencing, where applicable, in the text. The book, however, lacks a bibliography and distribution maps, which would have been helpful, especially as the book deals with species that are found both on the Continent of Europe and in the British Isles.

This book will contribute to the pleasure of outings to the sea-side and act as an eyeopener. It is a good buy at £8.99.

Margaret M. H. Lyth

THE PHYTOPLANKTON OF WINDERMERE
C.S. Reynolds and A.E. Irish

Freshwater Biological Association, Ambleside, UK, Special Publication, 2000, 73 pp., softback with colour photographs, charts and diagrams. ISBN 0-900386-65-7. £20.

The Freshwater Biological Association has played a pivotal role in the development of the understanding of processes and patterns in freshwater ecology over the last 70 years. It's true to say that its publications over this time have had a major influence on almost every aspect of freshwater ecology. This latest publication continues in this tradition. Highly authoritative, this short (73pp) summary by highly respected limnologists pulls together into a single source, 50 years of study into the seasonal and spatial dynamics of phytoplankton from Lake Windermere. In addition to their dynamics, Windermere catchment hydrology, the effects of a water quality restoration programme and the role of phytoplankton in the ecosystem are covered. As a case study of this fascinating group and man's impact upon them over time the long-term monitoring described in this work must be unrivalled anywhere. The descriptions of the results of these studies are clear, concise but also well referenced and accessible by anyone with some basic knowledge of aquatic systems. It is clear that this volume will act as a source –book for teaching material at senior secondary and undergraduate level for the next decade.

Colin Adams

WINDERMERE – RESTORING THE HEALTH OF ENGLAND'S LARGEST LAKE
A.D. Pickering

Freshwater Biological Association, Ambleside, U.K., 2001, 126 pp., softback with many colour photographs, maps and diagrams. ISBN 0-900386-68-1. £10.

The title of this volume would suggest that its focus would be on managing the effects of man on a large lake. In fact it is much more than that. Written in a style and format that is highly accessible to anyone with only minimal natural history knowledge, this book begins at the very beginning for Lake Windermere. Informed by some of the most extensive and long-term studies conducted in any freshwater lake, the author covers in an informative but simple style, the geological and glacial formation of the lake, its physico-chemical structure and the main groups of plants and animals that live there. In the second half of the book the focus in on informing the reader of the scale, scope and history of man's influence on Windermere and on the science behind how some of these changes are now being reversed. The author, a research scientist with very considerable experience, delivers the account with clarity and authority and has achieved the difficult balance between the technical and the popular. This volume should be of interest to all with an interest in our aquatic environment.

Colin Adams

KEYS TO THE FRESHWATER FISH OF BRITAIN AND IRELAND: WITH NOTES ON THEIR DISTRIBUTION AND ECOLOGY

Peter S. Maitland

Freshwater Biological Association, Ambleside, 2004, 248 pp., softback with 48 colour plates, 80 black and white line drawings, 55 distribution maps. ISBN 0-900386-71-1. £22.00.

The Scientific Publications series published by the Freshwater Biological Association began in 1935 with T.T. Macan's "Key to the British Species of Corixidae". Since then this series has transformed the study and practice of freshwater biology in all its facets. Providing the most authoritative, yet accessible, identification keys to practicing freshwater biologists over three generations, this series has rightly achieved high international acclaim and represents the best of academic achievement by a learned society.

The latest volume in this series, the 62nd, by Professor Peter Maitland, is a revision, update and extension of his original key to the freshwater fish of Britain and Ireland, published in 1972 as No. 27 in the series.

Much has changed in the 32 years since the first volume and these changes are reflected in this revision. Species have been added to the British list either through taxonomic changes (e.g. the Pollan, *Coregonus autumnalis*) or by the arrival of alien species to Britain (e.g. False Harlequin *Pseudorasbora parva* and Black Bullhead *Ameiurus melas*) but there have also been losses of species over the 32 years since the last volume. The sub-specific status of Sea trout / Brown trout, for example, is no longer recognised, as our understanding of the nature of life-history variation has deepened through research in the intervening years. In addition to the main key to families and a series of keys to the 57 species included, there are revised keys (to family level) based on fish eggs and scales and, new to the 2004 volume, a key for post-larvae to family level.

The legislative position of conservation, both in Britain and Ireland and more broadly throughout Europe, has changed dramatically since 1972 and a concise account of the current legislation with regard to freshwater fish is given as a useful, stand-alone section.

Other additions to the original key include a particularly useful description of the technique for the removal of fish pharyngeal bones (used in the identification of cyprinids), colour plates illustrating some of the species covered in the keys and an extensive updated bibliography to the identification, distribution and ecology of our freshwater fish fauna.

For all of those working in freshwater fish conservation, protection, research, management or training in Ireland and Britain, this is the most authoritative text on the identification of freshwater fish available. This volume will certainly remain the standard text for the identification of freshwater fish in Britain and Ireland for the next 30 years.

Colin Adams

COLLINS TREE GUIDE

Owen Johnson and David More

Harper Collins, London, 2004, 464 pp., hardback with many colour illustrations. ISBN 0-00-713954-3. £25.

The cover describes this as the most complete field guide to the trees of Britain and (non Mediterranean) Europe. If its predecessor, the late Alan Mitchell's field guide, is the standard to which such books should aspire, then in terms of sheer number of taxa described – 1600 compared with 800 – this book far surpasses the earlier one. Although its slightly greater bulk makes it less of a field guide it is nonetheless far from being the coffee table tome that the number of descriptions might suggest. Identification is provided not only for many taxa that are rare but also for some common natives such as elder or alder buckthorn that are often counted as shrubs rather than trees. This is quite acceptable when one appreciates the definition of a tree is somewhat imprecise.

The lack of dichotomous (paired statement) keys, such as are found in Mitchell, is arguably compensated for by a comprehensive number of illustrations of winter twigs, leaves and needles. Emphasis is placed on year round features such as habit, bark, shoots or needles rather than more transient (though botanically more absolute) features such as flowers and fruit. The book also possesses fewer references to tree locations than Mitchell, although it is doubtful whether such references should be part of a tree identification guide.

Although a non-dichotomous key to conifers in general occurs early in the book there are no keys to genera of either conifers or hardwoods. Instead Johnson, author of the text, lists spot characters for each genus followed by a number of 'key species' to assist in identification. Diagnostic features of each species are usefully highlighted by means of italics. A most useful subsection of each tree's description is that which compares the species in question with other similar looking but perhaps completely unrelated species. In such instances handy page reference numbers are given. Such comparisons are presented to an extent not found in other tree guides and are a reflection on the breadth of knowledge of Owen Johnson, who is a registrar at the Tree Register of the British Isles (TROBI). The fine, original, colour illustrations by David More are juxtaposed with the text, which is a great advantage.

Occasionally taxa are grouped according to their origin, e.g. silver firs from Europe, East Asia, West Asia and America; but a few appear to have been misplaced, e.g. the Colarado white fir is placed beside the Grecian fir. Such minor criticism should not detract from the fact that, if your interest in trees is anything rather than cursory, this book deserves a place in your bookcase. The cost of £24 represents good value for a hardback book of such high quality and extensive coverage. The book reviewed represents a smaller format of the larger version, which has a RRP of £40 (ISBN 0007191634).

Bob Gray

AN ILLUSTRATED GUIDE TO BRITISH UPLAND VEGETATION
A. and B. Averis, J. Birks, D. Horsfield, D. Thompson and M. Yeo

JNCC, Peterborough, 2004, 454 pp., softback with 16 colour plates, drawings, maps and diagrams. ISBN 1-86107-553-7. £25.

Anyone familiar, or perhaps over-whelmed, by the five volume National Vegetation Classification (NVC), the monumental work produced by Professor Rodwell in the 1980-90s, will find this book a fascinating overview of upland vegetation. The book has a simple aim: "to focus attention on the nature, diversity and importance of habitats which cover almost a third of Great Britain's land surface". An aim it well achieves.

The book provides a concise but informative introduction to the abiotic factors (e.g. geology, soils, climate, pollution and land use) that influence the vegetation found today. This is followed by background information on upland vegetation and technical considerations of comparison with European studies and classifications, and the national Biodiversity Action Plan (BAP) process, all of relevance to conservation within Great Britain. There is a very useful key to the vegetation, which starts by selecting out the broad habitat types, before providing clues to the vegetation communities.

The bulk of the book comprises the accounts of the 99 vegetation types represented in the uplands. It is a welcome feature of this book that all these types appear together rather than having to search through the five volumes of the NVC. The accounts are divided into the main habitats (woodland, mires, heaths, grasslands, wetlands and other open vegetation). Each account describes the key features of the vegetation followed by sections on identification, ecology, conservation value and management. There is also an up-to-date distribution map and the detailed line drawing provides clues of where to look in the landscape.

This information- packed book is the collaborative work of a group of keen and knowledgeable field botanists, familiar with the earlier works, notably of McVean and Ratcliffe in the Highlands, and the NVC, who have passionately applied their experiences. It is aimed primarily at practical field workers (surveyors, consultants, teachers, students, rangers etc.) and may be a little technical for some; a good knowledge of Latin plant names will help illuminate the text. However anyone wanting to understand and appreciate more of our rich upland heritage should definitely get hold of a copy. At £25 it is extremely good value.

Keith Watson

BOTANICAL LATIN
William T. Stearn

David and Charles, Newton Abbot, Devon, 4th edition, 1st softback edition, 545 pp., some drawings. ISBN 0-1753-1643-5. £19.99.

The first paperback edition of a classic work of botanical literature first published in 1966 is a working guide to the special latin, which is the international language used by botanists for the naming of plants and the description of plants new to science. It aims to supply a guide to grammar, standard procedures, peculiarities and basic vocabulary necessary for this purpose and also to allow access to older literature.

The Introduction sketches the historical development from classical latin, from which it has gradually become distinct. Part 2 gives grammar enough for a diligent student to become proficient. In Part 3, devoted to syntax, are given directions for writing diagnoses and descriptions necessary for describing plants with examples from all major groups. Further chapters add the terms required for plant habitats, geographical names and colours followed by one giving names derived from Greek words, leading to one on the formation of new botanical names and descriptive terminology. Part 4 gives 180 pages of comprehensive but not exhaustive vocabulary and a bibliography.

This 4th edition is published in a larger format than before with the addition of helps in composing botanical latin and 400 extra entries to the vocabulary. With these improvements this most accurate, up to date and comprehensive work is even more valuable and cheap at £20.

Ruth H. Dobson

PROVISIONAL ATLAS OF THE BRITISH AQUATIC BUGS (HEMIPTERA HETEROPTERA)
Thomas Huxley

Biological Records Centre, Huntingdon, Cambridgeshire, 2003, 118 pp., softback with distribution maps for each species, numerous line drawings. ISBN 1 870393 67 8. Obtainable from Publication Sales, CEH Directorate, Monks Wood, Abbots Ripton, Huntingdon, Cambridgeshire PE28 2LS, £8 including postage.

The atlases produced by the Biological Records Centre appear to have a misleading title. This is in the sense that the inclusion of the word provisional in their title gives the idea that they may be quite ephemeral publications. The distributional content can be updated at intervals to reflect developing awareness and activity, as is the case with this atlas on aquatic bugs. In addition there are substantial bodies of facts of general value to everyone from the general naturalist to the more focussed student or researcher. These include an updated checklist, general descriptions of the insects and backgrounds to data gathering and methodology. The maps give immediate gratification on where the bug is known to occur but the species accounts extend into biological information, ecological requirements and include hints on identification for that species. An appendix gives vice-county lists, advice on collecting, a glossary, index and bibliography. Most of the earlier accounts of water bug distribution by the same author were not produced by BRC but privately published. These were generally available to those involved with the actual recording or in those museums that Tom Huxley utilised as resources for data. Now the results are more widely accessible to everyone. The author and BRC, now part of the Centre for Ecology and Hydrology and the Joint Nature Conservation Committee, are to be congratulated on another valuable reference source.

E. Geoffrey Hancock

VERTEBRATE PALAEONTOLOGY
Michael J. Benton

Blackwell Publishing, Oxford, Third Edition, 2004, 455 pp., softback with numerous drawings and diagrams. ISBN 0-632-05637-1. £29.95.

Since the first edition was published in 1990, Michael Benton's book has been regarded as an excellent and accessible introduction to the history and evolution of the vertebrates. This welcome new edition brings *Vertebrate Palaeontology* up to date with the inclusion of the latest research and new finds from around the world. A few new features have also been introduced.

The main body of the text takes us chapter by chapter on a journey through time, following the major evolutionary developments of the vertebrates. After an opening chapter on the origin of vertebrates, sections include early Palaeozoic fishes, the early tetrapods and amphibians, the age of dinosaurs, the birds, the mammals and finally human evolution. There is also a chapter titled 'How to Study Fossil Vertebrates'. This examines the methods used to collect and prepare fossils, how they can be used in palaeoecological and other studies and also provides a brief explanation of cladistics.

A feature retained from the previous edition is the information boxes interspersed with the general text. These deal with specific topics ranging from 'The origin of snakes' to 'How many fingers and toes' to the examination of important fossil sites or faunas. The importance of Scotland in the study of fossil vertebrates is shown by the inclusion of four boxes dealing with Old Red Sandstone fish, Triassic reptiles from Elgin with the fossils from sites at Bearsden and East Kirkton, Bathgate. Many of these boxes have references directing the reader to helpful websites where further information can be found on the subject.

As in the previous edition, the author has included a further reading section at the end of each chapter with a few of the more important or popular works. This is very helpful for readers who do not want or need to delve into the very extensive bibliography. References to helpful websites are again included here. Another helpful feature is the inclusion of 'Key Questions' at the start of each chapter to direct the reader to important aspects of the topic.

Vertebrate Palaeontology is a textbook aimed at enthusiasts and undergraduates – Michael Benton is Professor of Vertebrate Palaeontology at the University of Bristol. However it is well laid out and the clear narrative style makes is accessible and easily read. I am sure anyone who wishes to learn more about the history of vertebrates will find it a very useful and informative book with much of interest to be gleaned.

Alastair Gunning

A FIELD GUIDE TO THE BIRDS OF BRITAIN AND IRELAND BY HABITAT
Mark Golley

New Holland Publishers (UK) Ltd., London, 2004, 208 pp., softback with numerous colour illustrations. ISBN 1-84330-576-3. £14.99.

This, the latest bird guide from the Wildlife Trusts, is aimed at the beginner to intermediate standard of birdwatcher. Over 280 species are featured, with information on identification, behaviour and calls together with over 1,000 colour illustrations. This guide is unusual in that it is organised by habitat, grouping bird species into the area in which you might see them, such as wetlands, coastal areas, woodland, farmland, urban areas, upland and heathland. This format however has been tried before, most notably in Lars Jonsson's excellent series of bird guides published in the 1970's for Penguin Books. One drawback is the lack of distribution maps. For instance from the text one might be led to believe that the Firecrest, though uncommon, is found in suitable woodland throughout Britain when this is certainly not the case. The text however is generally very good, as are Dave Daly's delightful illustrations. The flexible cover also makes this book ideal for carrying in the rucksack or pocket. In today's flooded market this guide stands out as good value and I would warmly recommend it to anyone with a developing interest in birds.

Sandy McNeil

THE NEW ENCYCLOPEDIA OF BIRDS
Edited by Christopher Perrins

Oxford University Press, Oxford, 2004, 656 pp., hardback, lavishly illustrated in colour throughout. ISBN 0-19-852506-0. £35.

Part of every home library should be dedicated to general reference works that are both useful and informative and this encyclopaedia does that job rather well as far as birds are concerned. It is lavishly illustrated with stunning photos and excellent artwork and covers all the known bird Families of the world. The text is divided into handy sections and is in a very readable style.

I particularly liked the "photo story" presentation style showing and explaining behaviour patterns of certain species in a two-page spread. Any single photo would convey little of the behaviour involved. So if you want to know what all the leaping about by Japanese Cranes means or how a Weaver builds its nest, then all is revealed. Other behaviour is illustrated by artwork of a very high standard. This is an excellent production and succeeds where others have tried and failed.

Today, large heavy tomes covering all the worlds birds family by family are published in volumes that cost an arm and a leg each. This review of the world's birds, all 656 pages of it, costs only £35.00, a snip at today's over-inflated prices. It is not huge but is heavy and is obviously not for carrying around but should be on the shelf of everyone interested in birds. The editor and his team are to be congratulated on a fine piece of work. I cannot but recommend it to all.

Bernard Zonfrillo

THE BTO/CJ GARDEN BIRD WATCH BOOK
Mike Toms

British Trust for Ornithology, Thetford, 2003, 128 pp., softback with many colour photographs, diagrams and tables. ISBN 1-902576-73-X. £9.99. Obtainable from GBW Booksales, BTO, The Nunnery, Thetford, Norfolk IP 24 2PU. Send cheque £10.99 payable to BTO or join GBW for £12 with book free.

Dedicated to the late Chris Mead, primary instigator of the Garden Bird Surveys, this delightful book is a mine of information. Informal in style it is pleasantly readable by beginners but also by knowledgeable experts since it mentions limits to what we know and topics for investigation, for instance, by the ongoing Garden Bird Watch (GBW) and related projects coordinated by the BTO. Thus the book provides interest and stimulus to both amateur beginners and experts. Lightweight and flexible, it is easily carried although the page-size (approximately 170-245 mm) is too big for most pockets.

The opening section, "Gardens for Birds", summarises the importance of gardens in our changing world. It gives practical suggestions on how to attract and study birds and other garden wildlife. The text is uncluttered by many practical details and data which are shown alongside in simple tables or diagrams. The ease of the collection and analysis of data using simple forms analysed by computer are explained. The GBW, growing and including over 16000 volunteer bird-watchers by late 2003, is probably the largest such team survey in the world. Its scale and duration, now over a decade, allow analysis to throw light on questions beyond the reach of lesser studies. It is organised to attract more watchers, who gain both interest from participation and from regular summaries and updates.

After a section on the behaviour, movements and general ecology of birds, "Species Accounts" deal with the 41 studied from the start of the scheme (Cannon, 1998), plus 10 others of occasional interest in gardens. The concise, narrative accounts are accompanied by marginal notes of status, foods, breeding and seasonal variation, with one or more small colour photographs mainly by Tommy Holden – not detailed as in guides but the limited kind of views one usually gets in practice.

A brief note on identification is followed by illustrated notes on distinguishing members of related or confusable groups (Pigeons & doves; Thrushes…Finches etc) and a selected list of useful books and addresses, a key to maps and figures and a table of varying seasonality of the main 41 species based on the GBW reports. Some are declining while others prosper, and the GBW study can document and sometimes help to reveal why these changes occur.

Findings from the GBW are not merely of interest but also of value for sound conservation, as the quality of other and "natural" habitats change. Chris Whittles, Chairman of DJ Wildbird Foods, wrote the foreword to this excellent book, and it is good to have their contribution to the effort. One need not be a BTO member to obtain the book, but new volunteer participants are welcome, whether members or not, and will soon enjoy more than their "moneysworth" from joining the team!

Reference

Cannon, A. (1998). *Garden Watch Handbook.* British Trust for Ornithology, Thetford.

Norman R. Grist

BILL ODDIE'S INTRODUCTION TO BIRD-WATCHING
Bill Oddie

New Holland Publishers (UK) Ltd., London, 2002, published in association with the Wildlife Trusts, 144 pp., with illustrations by David Daly (artist) and David Cottridge (photographer), ISBN 1-85974-894-5 hardback, 1-84330-016-8 softback. £12.99.

Those who have enjoyed Bill Oddie's refreshing, humorous, down to earth, observant and well-informed TV presentations will find the style reflected in this concise little book from the Wildlife Trusts. It is not a field guide as such but fulfils its role as a "perfect book for novice birdwatchers", while more experienced readers will enjoy its style and matter – above all practical: "..go and do it!". Information sources, choice of equipment, basics of identification, bird behaviour and songs, finding them, twitching, bird reserves and conservation are presented simply with leads to broader aspects and the practical use of collected data – even "birds in cyberspace", bird organisations and more advanced reading are concisely presented. The light-hearted text is supported by appropriate, attractive illustrations to illustrate the "jizz" and context of the birds.

Norman R. Grist

IRISH BIRDS
David Cabot

Harper Collins, London, revised edition 2004, 240 pp., hardback with numerous colour illustrations and maps. ISBN 0-00-717610-4. £14.99.

When I saw this book I looked forward to getting the chance to review it. Collins' guides are normally very good. David Cabot has done much good work. However this book was first published in 1995 and this is a revised edition and a lot could have been checked.

The book has been designed for those with a general interest in birds, Irish or not; it aims to take the fear out of identifying birds and that is an excellent idea. But it is a pity that more care was not taken with illustrations: they are from the 1980s and perhaps earlier, cut and pasted into the text. The tits are awful, the lapwing characterless, the pied wagtail has two pairs of claws. Some care should have been taken with cropping and editing and it is a great shame that the pictures all look cut out and stuck somewhere where they fitted. The quality of bird art is now so good that such illustrations totally spoil a book.

The bird keys are though useful. The provision of places to visit very good indeed, though the spelling of "Monoghan" took me aback as I usually think of Monaghan. The division

of the book into habitats was therefore relevant to site visits. I liked the use of Irish Gaelic bird names. But looking into the text I was expecting more, forgetting the general nature of the book. I was surprised that the peculiar brown colouring of immature Irish male hooded crows did not seem to be mentioned. Yes, it is a general book, but these are such curiosities that I thought they would have been highlighted and surprised me years ago at Howth.

Possibly this book would use very well with web sites and many are provided. With increasing I.T. this may well become the bird watching of the future but I hope not as I still value bird books. As a general text this Irish birds book promised much but in the end was personally disappointing. I would like to see how well it works in the field, I think it might do well away from fault finding. That is why I've almost personalised this book review as I think people should see the book and assess it for their own needs, use it as a general guide. There is a great natural world in Ireland and more birding texts would be preferable to the bomb and bullet histories that proliferate.

Brian S. Skillen

DORMICE
Pat Morris
Illustrated by Guy Troughton

Whittet Books, British Natural History Series, (email Annabel@whittet.dircon.co.uk), printed by Cromwell Press, 2004, 144 pp., hardback with 50 line illustrations. ISBN 1-873580-64-9. £9.99.

Pat Morris is the well-known author of many publications on small mammals including hedgehogs. With his illustrator Guy Troughton he has produced this excellent publication with its delightful drawings, maps and cartoons.

The distribution maps show that the two species that occur in the UK are mostly in the southern half of England. There is the attractive hazel dormouse, *Muscardinus avellanarius* that is becoming a rare mammal and requires protection and encouragement to extend its range. The other species is the edible dormouse, *Glis glis* which is considered a pest due to its predilection to take up residence in lofts of houses where its nocturnal habits cause disturbance in the middle of the night and it is guilty of gnawing electric cables. This species is fortunately restricted to Buckinghamshire and Hertfordshire.

Although the book is a good read there is plenty of hard scientific information to satisfy the researcher. The author covers in detail the distribution, food and ecological requirements of both species. The book draws on the extensive fieldwork in which the Author has been involved over many years. He has been active in trying to regenerate the hazel dormouse population by protective breeding schemes. In order to locate existing populations he explains how to identify areas where you find this attractive rodent. The usual way is to examine hazelnut shells to determine what has been feeding on them. That section in the book will enable you to say if a dormouse, wood mouse or woodpecker has been feeding on the nuts.

In conclusion, for anyone interested in this attractive animal, this publication is an excellent buy at £9.99.

Ian C. McCallum

ESSENTIAL ANIMAL BEHAVIOR
Graham Scott

Blackwell, Oxford, 2004, 202 pp., softback with numerous colour photographs and diagrams. ISBN 0-632-05799-8. £22.99.

The aim of *Essential Animal Behavior* is "to provide a concise but thorough introduction to the study of animal behaviour". Although it is written primarily for undergraduate students it has much to offer the naturalist who wishes to understand why animals behave in many different ways. Niko Tinbergen, the pioneer of ethology believed that to understand behaviour we must explain the causation of the behaviour, its evolution, its function and its ontogeny. The author takes this approach by first examining the role of the nervous system in controlling behaviour and the motivation underlying different behaviours and biological rhythms. The evolutionary reasons behind behaviour are first looked at from the point of view of how genes may control behaviour and the balance between innate and learned behaviours. This is illustrated in the case of pigeons where homing behaviour is controlled by a complex interplay of factors including compass setting from the position of the sun and the magnetic field and navigation based on olfactory cues and landmark recognition. Communication principles behind signals, alarm calls and individual recognition are covered; also demonstrating how the study of chemical signalling by pheromones can be applied to control insect pests. The behavioural decisions about what to eat draws on the latest research on optimal foraging in birds (some of which was undertaken at the University of Glasgow). Finally, the reproductive behaviour of a range of species is described showing how mate choice strongly influences behaviour.

Overall the book is creatively set out with inset boxes to explain key concepts and examples. The diagrams and graphs are exceptionally good, facilitating the interpretation of complex results and colour photographs illustrate many of the species described. The author's fascination with animal behaviour is evident and he convincingly demonstrates how the study of animal behaviour has been able to improve the welfare of animals in captivity and how it can be applied to the management of wild populations. If you are always wondering why animals are acting in unusual or different ways this book will help to explain the reasons.

Dominic McCafferty

PROCEEDINGS 2004

The Chairman, place, lecturer's name and title of lecture are given for most meetings.

GKB - Graham Kerr Building

13th January
Roger Downie, GKB,28, Paisley International Colour Slide Exhibition. Compiled by members of Paisley Photographic Club, presented by Winifred Brown and projected by Jim Campbell.

10th February
Roger Downie, GKB, 31,"Encapsulating Field Mycology", speaker Roy Watling.

24th February
Roger Downie, GKB,34, 74th AGM. Reports were given about activities during 2003 and elections were held. Membership stood at 258 made up of 180 ordinary, 38 concessions, 32 family, 5 honorary and 3 school members. There were 3 council meetings and 4 BLB meetings held during the previous year.
The AGM was followed by Peter Meadows talking about Noah's Flood.

9th March
Roger Downie, GKB,39, "Plant hunting in Tibet", speaker Kenneth Cox

6th April
Morag Mackinnon, GKB, 23, Members Slide Night.

11th May
Roger Downie, GKB,35, "Flying to the tropics: investigations into the diversity of hoverflies and other insects of the New World", speaker Geoff Hancock.

8th June
Summer Social to Balmaha.

Excursions
17 excursions took place throughout the year.

21st September
GKB, Exhibition meeting with wine and cheese.

19th October
Roger Downie, GKB, 34,"Climate change and Scotland's natural heritage", speaker Noranne Ellis of SNH.

9th November
Roger Downie, GKB, 40,"The natural history of Kamchatka", speaker Malcolm Kennedy

17th November
Roger Downie. Western Infirmary Lecture Theatre. Fourth BLB Lecture. "The complex mating games of insects", speaker Tracy Chapman.

27th November
Roger Downie. GKB One day conference on "The Natural History of Loch Lomond and the Trossachs"

14th December
Glasgow University Club. Christmas Dinner.
The meal was followed by slides from Aidan McCormick on "The rare birds of Bolivia".

OFFICERS AND COUNCIL ELECTED AT THE AGM ON 25TH FEBRUARY 2004.

President
Roger Downie, B.Sc., Ph.D.

Vice Presidents
Bob Gray, B.Sc., M.I.Biol.
Richard Weddle, B.Sc.
Norman Grist, B.Sc., M.B., Ch.B., F.R.C.P., F.R.C. Path

General Secretary
Mary Child,

Assistant Secretary
Fiona Giffard, B.Sc. (Minutes)

Treasurer
Morag Mackinnon, B.A., B.Sc.

Librarian
Joan Chapman

Assistant Librarian
vacant

Editors
Azra Meadows, B.Sc., M.Sc., Ph.D.
Peter Meadows, M.A., B.A. Open University FIBiol.

Newsletter Editor
J Jocelyn (Geology) (D Palmar substituted)

Membership Secretary
Richard Weddle, B.Sc.

Publicity Secretary
John Lyth, B.Sc.

Social Secretary
Hazel Rodway

Councillors
Ian McCallum, C.Eng., M.I.C.E., F.I.H.T. (Excursions)
Janet Palmar
Ruth Dobson, B.Sc., M.Sc.
Robin Jones
Edna Stewart, B.Sc.
David Palmar

Section Convenors
Bio-diversity – R Weddle
Botany - Keith Watson
Computer - Richard Weddle
Geology - Julian Jocelyn
Ornithology - Sandy McNeil
Photography - Sandy McNeil
Zoology - Geoff Hancock
Excursions - Joyce Alexander

BLB Financial Advisors – Gerrards
BLB Scientific Advisor - Peter Macpherson , F.R.C.P., F.R.C.R., D.T.D.C., F.L.S.

THE GLASGOW NATURALIST
Advice to Potential Contributors

Please note that the following advice and instructions have been changed from previous issues of the journal.

1. The Glasgow Naturalist publishes papers, short notes and book reviews. Book reviews are commissioned. Books reviewed are kept in the Society's Library. Papers and short notes must be word processed in Microsoft Word. They should normally be submitted electronically either as word attachments to an email, or on disc. They should be sent to The Editors, Azra and Peter Meadows, The Glasgow Naturalist, DEEB, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland (email: gbza31@udcf.gla.ac.uk. Or gbza21@udcf.gla.ac.uk).

Papers and notes are refereed. Acceptance of articles and short notes is the responsibility of the Editors. The journal is published approximately yearly. Papers and short notes not presented in the format and style listed below will be returned to the authors for editing before they are refereed.

Papers and short notes are welcomed on any aspect of the natural history and ecology of Scotland, including freshwater, marine and terrestrial ecosystems and species, climate change and environmental management, botany, geology and zoology, field and laboratory studies, environmental engineering, socio-ecology, and historical treatments of ecosystems or natural historians.

2. Papers should be substantial accounts of scientific or related work. They should not exceed approximately 6000 words including references and equivalent space for tables and references. Longer articles must be discussed with the Editors before submission. Articles should be headed by the title, the author's name and address.

The text should normally be divided into sections with sub-headings as follows: Abstract, Introduction, Methods, Results, Discussion, Conclusions, Acknowledgements, References.

This format may be less suitable for certain articles, such as historical accounts. Consult the Editors if in doubt.

3. Short notes should not normally exceed one page of A5 single-spaced. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new stations for a species, rediscoveries of old records, additions to records in the Atlas of the British Flora, unusual dates of flowering, unusual colour forms of plants or animals, ringed birds recovered, weather notes, occurrences known to be rare, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.

4. References in articles and short notes must be given in full (please do not abbreviate journal titles) according to the following style:

Pennie, I.D. 1951. Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.

Wheeler, A. 1975. *Fishes of the World.* Ferndale Editions, London.

Grist, N.R. & Bell, E.J. 1996. Enteroviruses. Pp. 381-90 in Weatherall, D.J. (editor) *Oxford Textbook of Medicine.* Oxford University Press, Oxford.

It is the **author's responsibility** to ensure that all references in the text are in the reference list at the end of the paper or short note, and vice versa.

5. Nomenclature of vascular plants should be as in Stace, C.A. (1997). *The new Flora of the British Isles* (Second Edition). Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply. Use lower case initial letters for all common names e.g. wood ants, blackbirds, unless the common name includes a normally capitalised proper name e.g. Kemp's ridley. Where giving distribution information by vice-county, use the following style: VC 30.

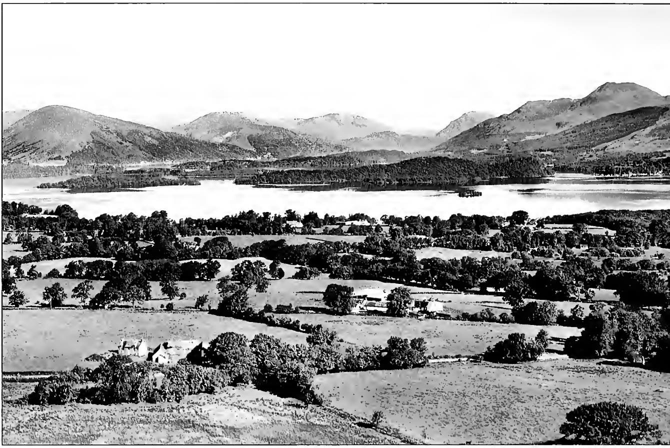
6. Typescript font and font size. Papers and short notes should be presented in **Times Roman font size 10**, escept for tables and figures which should be in Times Roman font size 9.

7. Tables and Figures must be supplied in electronic form as black and white. Please do not include them within the paper or short note. Place them at the end of the paper, or as separate files. They are numbered in Arabic numerals e.g. Table 1 or Figure 1. Figures and tables should be numbered separately. If a figure or table has separate parts it should be identified as 9 (a), 9(b) and so on. Use **Times Roman font size 9** for all contents of tables and figures. Each figure or table should have a legend. Figures and tables should preferably fit within one column of the journal. This means that they should be **less than 7.5 cm** in width. If this is really not possible they must fit within two columns of the journal and should be less than 15 cm in width. Figures are of two types. The first consists of graphs, histograms, scanned drawings, or flow charts. The second consists of black and white photographs. A metric scale must be inserted in micrographs etc. The Editors may able to accept a very small number of high quality colour photographs for each issue. Please consult the editors before submitting colour photographs.

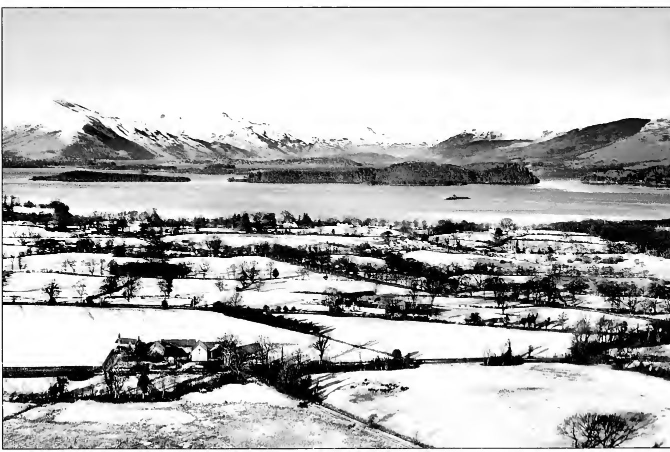
8. Proofs. One set of proofs will be supplied to the author in hard copy. It should be returned to the Editors by return of post. Alterations should be kept to the correction of typographical errors. More extensive alterations are not normally allowed.

9. Offprints. Ten offprints and one complimentary copy of the Journal are provided free of charge. Further copies may be purchased, provided that they are ordered at the time the proofs are returned.

10. Review. All submissions are reviewed by the Editors or their appointed referees. They are also assessed by the Editors or their appointed referees for ethical considerations. After authors have considered and responded to referees' comments, acceptance of the revised manuscript is the editor's decision.



A view of the south end of Loch Lomond in summer as seen from Duncryne Hill near Gartocharn.



The same view of the south end of Loch Lomond in winter.
(photographs courtesy of John Mitchell)

The Glasgow Naturalist

Volume 24 Part 4 2006

Journal of
THE GLASGOW NATURAL HISTORY SOCIETY

GLASGOW NATURAL HISTORY SOCIETY

(formerly The Andersonian Naturalists of Glasgow)

The object of the Society is the encouragement of the study of natural history in all its branches, by meeting for reading and discussing papers and exhibiting specimens and by excursions for field work. The Glasgow Natural History Society meets at least once a month except during July and August, in the University of Glasgow, the Glasgow Art Gallery and Museum, or Hillhead Library.

The present rates of subscription per annum are: for Ordinary Members, £17: Family Members, £3 extra; Junior Members (under 21) £8; School Members, £1. Payment by Direct Debit is encouraged.

Further information regarding the Society's activities and membership application forms are obtainable from the General Secretary, The Glasgow Natural History Society, c/o DEEB, Graham Kerr Building, University of Glasgow, G12 8QQ, Scotland. The Glasgow Natural History Society website is http://www.gnhs.freeuk.com/, which also contains details of the Glasgow Naturalist.

The Glasgow Naturalist

The Glasgow Naturalist is published by the Glasgow Natural History Society. ISSN 0373-241X. Price £4.25 plus p.& p (as applicable at the time of posting). The Glasgow Naturalist is free to members.

Editor from volume 25 part 1 onwards: Dominic McCafferty, DACE, St Andrews Building, University of Glasgow, 11 Eldon Street, G3 6NH, Scotland (Email: D.McCafferty@educ.gla.ac.uk).

Contributions are invited, especially when they bear on the natural history of Scotland. Full details of how to contribute articles or short notes are given at the end of the volume. A limited number of advertisements can be accepted and enquiries should be sent to the Editors.

This publication is included in the abstracting and indexing coverage of the Bioscience Information Service of Biological Abstracts and the Botanical Society of the British Isles Abstracts.

The following back numbers are available for purchase in their separate parts:

Vols.II - VII (1890-1918); Vols. XIII - XXIII (1937-1999).

Of the earlier Journals the only parts available are:

Proceedings and Transactions of the Natural History Society of Glasgow Vol. II pt. 2; Vol. VI pt. 1; Vol. VII, pt. 3; Vol. VIII, pts. 1 & 2.

Enquiries regarding prices of and orders for any of the above, or for reprints or photocopies, should be addressed to the Librarian: Mrs Joan Chapman, 121 Randolph Road, Jordanhill, Glasgow G11 7DS, Scotland.

Publications of Glasgow Natural History Society

Alien Species: friends or foes? Edited by J.R.Downie (2001). Proceedings of the GNHS 150th Anniversary Conference. Price £10.00 plus p & p.

Bound copies of the following may be obtained from the Librarian at the address above and at the prices shown:

The Flora of the Clyde Area (Original printing). J.R. LEE, Price £11.00 to members of GNHS and to the book trade; £13.50 to others (p. & p. £1.00 extra). This is still the only work of its type and is in diminishing supply. A few unbound copies are available: £5 (p.&p. £1 extra).

The Flora of Ailsa Craig. B. ZONFRILLO, 1994. Price £2.50 plus p.& p.

The Natural History of the Muck Islands, N. Ebudes:

Introduction and Vegetation with a List of Vascular Plants. R.H. DOBSON & R.M. DOBSON, 1985. Price £1.00 plus p. & p.

Seabirds and Wildfowl. R.H. DOBSON & R.M. DOBSON, 1986. Price £1.00 plus p. & p.

Landbirds. R.H. DOBSON, 1988. Price £1.00 plus p. & p.

The following bound reprints from the *Glasgow Naturalist* may be obtained from the librarian at the above address and at the prices shown.

Additions to the Flora of the Clyde Area. John R. Lee (1953). £1 (p.&p.)

Archives

For archive information and special collections of the GNHS contact Karol Magee, Tel. 0141 287 2907.

Society Microscopes

The Society incorporates the Microscopical Society of Glasgow. Microscopes may be borrowed by members and are currently kept in the room of E.G. Hancock, Curator of Entomology, in the Graham Kerr Building, University of Glasgow.

Front Cover Glen Falloch looking south to Ben Lomond. Artist: George Fennel Robson 1788 – 1833.
See paper by John Mitchell.

Back Cover Upper photo. Reconstruction of *Leedsichthys problematicus* by Bob Nicholls, Palaeocreations (**www.paleocreations.com**). See paper by Jeff Liston.

Lower photo. Salt marsh bordering upper intertidal zone of Ardmore Bay, Firth of Clyde.
See paper by Meadows, Meadows, Flowers and Qureshi.

The current volume and part (volume 24 part 4), is the last that is edited by Azra and Peter Meadows.

The Glasgow Naturalist Volume 24 Part 4 2006
CONTENTS

OBITUARY

PROCEEDINGS AND OFFICERS

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 1-5.

THE GLASGOW NATURALIST
EDITORIAL REVIEW

Azra Meadows and Peter Meadows
Division of Environmental and Evolutionary Biology,
Institute of Biomedical and Life Sciences,
University of Glasgow, G12 8QQ
Email:<gbza31@udcf.gla.ac.uk>

INTRODUCTION

This is the last of our three years as editors of the Glasgow Naturalist. The high quality of the contributions received during this period from both amateur and professional biologists shows the very important contribution that the Glasgow Natural History Society makes to natural history in all its aspects, covering issues in Scotland and on a wider national and international stage. This is especially important as climate change moves to the centre of ecology and geopolitics. Here, a better understanding of the taxonomy, distribution and ecology of freshwater, marine and terrestrial species and of their ecosystems is vital. This in turn will develop our ability to assess and then deal with the adverse affects associated with the current era of rapid climate change that is caused by man's activities.

The Glasgow Naturalist therefore has a unique role to play in our understanding of the ecology and biodiversity of terrestrial, freshwater and marine environments in Scotland and internationally. In our previous editorial, we listed the major topics covered by the journal. We list them again here, so that the breadth of cover by our contributors is recognised by readers of the journal here in Scotland and abroad, and also be potential contributors.

Biodiversity at all its levels including plants, animals and microorganisms.
Taxonomic descriptions of new and rare species.
Field studies of species and ecosystems.
Experimental studies of species and ecosystems.
Wildlife conservation and management.
Environmental management and impact assessment.
Historical and archaeological aspects of natural history.
Lives and activities of eminent natural historians
Environmental implications of waste management.
Implications of climate change.
Environmental geomorphology.
Environmental engineering.
Eco-sociological issues.
Environmental economics and policy.

As we have previously pointed out, members of the Glasgow Natural History Society, and our amateur and professional contributors, are essential for the success of the journal, and to its continued development as a prestige journal from the West of Scotland. They continue to achieve these objectives. We hope that our successors as editors will agree that the Glasgow Naturalist should therefore provide a journal that continues to be interesting and topical especially in relation to climate change, as follows.

- Production of a journal that is 21st century orientated in its contents and presentation.
- Encouragement of high quality papers on Scottish topics or topics that have relevance to local and national issues in Scotland, and that are also of interest internationally.
- Stimulation of a broadening of the breadth of subject areas of submitted papers, including all aspects of freshwater, marine and terrestrial ecosystems and species in Scotland.
- Encouragement of younger biologists, whether amateurs or professionals, including postgraduate and undergraduate students, to submit quality research and review articles and short notes.
- Provision of an effective professional standard of refereeing and editing for the journal.
- Provision of leadership for amateur and professional contributors to the journal in relation to subject topic and paper layout for the journal, especially in relation to current electronic facilities.

THE CURRENT VOLUME OF THE JOURNAL. VOLUME 24 PART 4 2006

The current issue of the journal contains papers covering a wide spectrum of subjects. These include 19th century painters and photographers views of Loch Lomondside emphasising the interaction between art and the Scottish environment, the enormous Jurassic bony fish *Leedsichthys problematicus,* the fisheries of the Clyde Sea area, two seminal papers on the insects and other invertebrates of the Island of Rum, and a timely review of climate change and the Stern Review.

The recently published Stern Review on the Economics of Climate Change (Stern, 2007) and the February 2007 release from the International Panel on Climate Change (IPCC, 2007), have been dramatic reminders of the impact now and in the future, of the effects of global warming. The warming has largely been produced by the activities of man releasing carbon dioxide into the atmosphere, where it and related compounds, together called greenhouse gases act as a blanket inhibiting energy loss from the earth into space. Azra and Peter Meadows consider the Stern Review and other recent literature, in terms of the effects of climate change on Scotland. They firstly provide a background to the global gain of energy from the sun and loss of energy irradiated back into space, and follow this with graphs illustrating how quickly global warming has taken place over the last one hundred and fifty years. Effects are already noticeable on the abundance and distribution of key indicator species, however the effects on global and local ecosystems will become much more pronounced over the next fifty years. The paper lists potential impacts on water, food, health, land and the environment, and considers the likelihood of these and the occurrence of abrupt and large scale events for progressively larger increases in global temperature. The authors follow Stern by considering the impacts on and costs for developing and developed countries, and highlight one example – the difference between changes in cereal production in the two groups of countries. They then discuss in detail the potential impacts on Scotland and the Scottish Economy.

Glyn and Dawn Davis provide an interesting account of the self seeding and epiphytic habit of the New Zealand tree *Griselinia littoralis.* As the authors point out, *Griselinia littoralis* is a shrub or small tree, native to New Zealand – being common in lowland and mountain areas there. It is popularly grown in mild coastal areas of the UK as an attractive evergreen shrub with apple-green (or variegated) leaves. The species is also used a hedging plant because it is resistant to salt, although does not grow well in frost prone areas. Glyn and Dawn Davis have studied the species on the Isle of Bute and elsewhere, where the seedlings growing epiphytically, out of the reach of deer, and in fenced areas where deer are excluded. They conclude from their observations, that grazing by deer may be significant in relation to the paucity of observations of self-seeding in the species.

The development of artificial marine reefs to provide habitats for fish and other species as an aid to improving the biodiversity of inshore marine waters has recently become highly topical. William Hunter reviews this globally important area of marine ecosystem management, starting with the artisanal use by local fishermen aimed at increasing local fish stocks, to their current use in twenty two countries for a wide range of ecosystem management procedures. He points out that there has often been a lack of replication in these studies leading to a lack of scientific accuracy, and that economic and legal factors often have limited the study of artificial reefs. His review, intitled 'artificial reefs: a review and critical perspective' has much relevance for the inshore waters around Scotland. The editors are especially pleased with this contribution, as it by a young environmentally dedicated biologist who undertook the work as part of his work placement experience during his BSc degree.

Jeff Liston writes a most unusual article entitled 'From Glasgow to the Star Pit and Stuttgart: A Short Journey Around The World's Longest Fish' illustrated with some unique archival photographs. The story is fascinating, and concerns the enormous Jurassic bony fish *Leedsichthys problematicus.* It has also earned Jeff a very well deserved PhD from the University of Glasgow – one of the editors of the Glasgow Naturalist was the internal examiner. Jeff identifies the Ferrier Fergusson family of Glasgow's West End as being the start of the story. The family was connected to the Tennant family as Henrietta Fergusson and her cousin Margaret Galbraith both married the Tennant brothers who founded the chemical company in their name. Mary Ferrier Fergusson, who was the sister of Henrietta, married Alfred Nicholson Leeds a gentleman farmer of Eyebury near Peterborough, who was to become the collector of the most extensive collection of Jurassic marine reptiles ever. This included bones of *Leedsichthys problematicus*, the tail bones of which took nine months of work by Alfred and Mary to stick together. There were apparently thousands of bone fragments involved. After Alfred's death, Mary Fergusson donated Alfred's collection, including *Leedsichthys problematicus* to the Hunterial Museum of the University of Glasgow. Jeff Liston's paper follows this convoluted story and provides an insight into the vagaries of family history, of palaeontological research, and of a visit to Star Pit on 22nd October 2001 for bones of a new specimen.

Peter Macpherson and J. R. Hawell report an extension of the distribution of Dyer's Greenweed (*Genista tinctoria*). Their account shows how dedicated many amateur and professional ecologists can be. We quote verbatim: ' While travelling south on the M74 on 1st July 2004, one of the authors (JRH) noted small clumps of Dyer's Greenweed (*Genista tinctoria*) on the grassy embankment of the southbound carriageway, between Junctions 12 & 13. Returning on 13th July he noted two patches on the northbound embankment approximately three miles south of J 12. The following day he walked across moorland adjacent to the M74 until he reached the most extensive patch on the southbound embankment, where the plant covered an area of approximately three square metres.' How does one explain to any passing Police Patrol car what one is doing under these conditions?

Dyer's Greenweed is a small deciduous shrub that occurs sporadically on calcareous or slighty acid clays, in a wide range of habitats including rough pastures, heaths, and the edges of fields and roads. The species is not common and has declined since the 1940's. So the record is important, and gives one of many examples showing the significance of the Glasgow Naturalist as a repository for unusual records or extensions of distribution.

Fishermen working the North Sea and the Clyde Sea area have a wealth of historical and scientific knowledge and anecdotal information. Unfortunately much of it goes unrecorded, partly because some professional fish biologists regard the information as none too accurate. The current editors of the Glasgow Naturalist do not hold this view, in fact very much the reverse. So when an opportunity occurred to ask a very experienced skipper of the Clyde Sea Area to voice his views, and say something about the history fisheries of the area, they were delighted. Howard McCrindle, currently skipper of R.V. Aplysia at the University Marine Biological Station, Millport, Isle of Cumbrae, has an almost unique knowledge and long-term experience of the Clyde Sea area and its fisheries. He records this history from the 1950's to the present day starting with the herring fisheries. There are many interesting parts to this story, including the use of pairs of boats, ring netters, bottom and mid-water trawling, and the introduction of echo sounders and net monitors. He also records the invasion of the fisheries by French and Spanish fishing vessels. The story entitled 'Cleaning the Clyde - a fifty year fisheries revolution' is a fascinating one to any biologist who knows the Scottish west coast marine scene.

Plants growing at the edge of rivers, estuaries and marine coasts often protect the shoreline from erosion and act to conserve endangered habitats such as salt marshes. Gerrit Klemm, Alan Ervine, Azra Meadows and Peter Meadows have been studying their protective effect for some years, and now publish for the first time the results of some of their laboratory investigations on a common saltmarsh fringe plant from the Clyde Estuary, *Spartina anglica*. By using a large-scale flume in the Department of Civil Engineering at the University of Glasgow, they have demonstrated that stands of the plant have a major effect on water flow by reducing water velocity and increasing water turbulence. These changes, which in the field will occur as the ebb and flow of the tide and the river's flow pass through the Spartina fringe, are likely to inhibit the erosive tendency of the water movement, hence preserving the landward salt marsh. The authors suggest that an integrated laboratory and field investigation of the protective role of Spartina on a selected salt marsh should be conducted.

One of the features of the west coast of Scotland is its wide range of intertidal environments, many of which are sandy or muddy. Azra Meadows, Peter Meadows and Hugh Flowers of the University of Glasgow, and Naureen Qureshi of the Centre of Excellence in Marine Biology at the University of Karachi, describe one of these, Ardmore Bay in the Firth of Clyde. They focus on the visible traces of physical, chemical and biological interactions on the surface of sediments and within the sedimentary column. Most of these traces can be seen with the naked eye by the non specialist, so the picture has an immediacy that is sometimes lost in sophisticated experimental or field analyses of intertidal ecosystems. The redox discontinuity layer separating aerobic from anaerobic sediments is one such chemical trace that can be easily seen by digging into the sediment. This separates the upper light brown aerobic sediment from the lower grey or black anaerobic layer that smells of hydrogen sulphide (rotten eggs). Biological traces are everywhere, and consist of invertebrate infaunal burrows within the sediment, and tracks or marks at the sediment surface made by invertebrates, fish and birds.

John Mitchell, in the first of his two articles in this issue of the Glasgow Naturalist, records the discovery of the little known water starwort *Callitriche palustris* L. in ponds on Loch Lomondside in August 2000. The site is former haugh-land (low lying flat land that is prone to flooding) that had been embanked and drained in the 19th century for the growing of arable crops, but was then abandoned and allowed to re-flood. The very dry summer in 2005 enabled the author to confirm the record in and to describe the field characteristics of the terrestrial form of the species on dry mud flats. He reports that young specimens of *C. palustris* are initially very compact, and superficially have the appearance of a condensed spider's web, before the individual stems elongate as they spread outwards. Short papers of this sort are an integral part of the corpus of work that continues to be reported in the Glasgow Naturalist. They are very much welcomed by the editors from either amateur biologists or professional scientists.

In the second of his two articles, John Mitchell describes the early landscape artists and photographers who have depicted the Loch Lomondside area. The article is the last in a series of six that have focussed readers interest on the historians, geologists, geographers, naturalists and artists who have left a written or pictorial record of Loch Lomond and its surroundings. It is a fascinating account, and represents an outstanding example of the interaction between art and the environment. The author quotes John Morrison in 'Painting the Nation: Identity and Nationalism in Scottish Painting, 1800-1920' published in 2003 as writing "Most historians have had little concern for art as evidence". The same is true of scientists. Neither view is one subscribed to by the current editors of the Glasgow Naturalist. Both historians and scientists can learn a great deal from art. One only has to look at the late eighteenth century oil paintings of snow in southern England and ice on the Thames – the Ice Fairs during the Little Ice Age, and compare these with the current global warming scenario. The paper includes short biographies of the following painters and photographers - an impressive list.

Paul Sandby (1725-1809)
Joseph Farington (1747-1821)
George Garrard (1760-1826)
Alexander Nasmyth (1758-1840)
Joseph Mallord William Turner (1775-1851)

John Knox (1778-1845)
George Fennel Robson (1788-1833)
John Fleming (1792-1845)
Horatio McCulloch (1805-1867)
George Washington Wilson (1823-1893)
James Valentine (1815-1879)
Thomas Annan (1829/30-1887)

The illustrations in John Mitchell's article are a delight to the eye. They also suggest that the area is one that demands a long-term study, broadening the coverage to the whole of Scotland, although the author's view is that "a very cautious approach is required before accepting any early landscape sketch or painting as portraying a reasonably accurate representation of the chosen scene". He does go on however to demonstrate a very clear appreciation of the potential. "Woodland historians have on occasions taken this step, showing that the less romanticised or impressionistic landscape studies can be a source of material on which to make a qualified judgement as to the extent of the tree cover, or in identifying major changes which have since taken place. Such pictures have proved particularly useful where maps and documentary sources for a given area or period are few or entirely lacking". The introduction of photography in the early part of the nineteenth century has also provided an objective quality control as Mitchell points out, and the Annan family of Glasgow were and still are at the centre of this photographic recording.

Parasites of marine crustaceans are not widely known to the broader scientific public. It is even more unusual to find that some of these parasites are crustaceans themselves. Myles O'Reilly, in a very interesting paper, describes a number of such cases. The animals belong to an unusual group of parasitic Crustacea the Tantulocarida, made up of about 1200 species ectoparasitic on copepods, isopods, ostracods and tanaids in deep sea environments. Non parasitic stages of some species have been recorded in meiobenthic communities. The species in the group are very small, being less than 300 microns in length (0.3 mm), and have a much reduced body form. The thorax is unsegmented, and the abdomen is much reduced. The author records the presence of three species in Scottish waters, *Microdajus langi*, *Amphitantulus harpiniacheres*, and probably *Cumoniscus kruppi*. What is important about these records is that the species were found on hosts collected in shallow water near the Scottish coastline, being previously recorded from deep water in the Rockall Trough west of Scotland in the North Atlantic, a rough-weather area well known to the editors. Clearly the global distribution of the Tantulocarida in relation to water depth needs to re-examined.

Climate change is rapidly detected in the changing patterns of animal and plant distribution, and so records of individual species and large scale surveys are especially important at the present time. It is most timely, therefore, that two such surveys are published in the current issue. Both are on terrestrial invertebrates found on the island of Rum which lies about 12 miles west of Mallaig and separated from the Isle of Skye to the north east by the Cuillin Sound. This is especially significant, because island communities have an added significance because of their isolation. Gordon Corbet compiles and edits a paper on the terrestrial invertebrates excluding insects on the island, and Peter Wormell does the same for the insects. Both papers are massive undertakings, involving a large number of dedicated amateur and professional field biologists. The compilers and editors, and the field workers are to be congratulated on a truly mammoth undertaking. The people who contributed to one or other or both of the papers are as follows.

C Allen	Lepidoptera
D Barbour	Lepidoptera
K Bland	Lepidoptera, Diptera, Hymenoptera, Odonata, Hemiptera, mite-galls
D Beaumont	Arachnida, Coleoptera
S Blake	Coleoptera (Carabidae)
G Corbet	Arachnida, Mollusca, Crustacea (Isopoda), Diplopoda (Millipedes), Chilopoda (Centipedes), Hemiptera, Neuroptera, Diptera, Hymenoptera, arachnids, molluscs, myriapods
M Davidson	Arachnida, myriapods
D Horsfield	Diptera, Lepidoptera
R & R Key	Coleoptera, Odonata, Hymenoptera, Diptera
J MacKay	Lepidoptera
D Phillips	Diptera (Tipulidae), Odonata, Orthoptera, Hymenoptera
R C Welch	Coleoptera, Lepidoptera, Siphonaptera
P Wormell	Lepidoptera, Hemiptera

The short notes section contains interesting comments on the distribution of the False Lupin Thermopsis montana in Lanarkshire by Peter Macpherson and B. Simpson, a note on Alexander Patience (1864-1954) by Geoff Moore, and three short notes by Myles O'Reilly. The first of these is a new record of the amphipod *Microjassa cumbrensis* in the Forth Sea area, the second on the Japanese Macho Skeleton Shrimp (*Caprella mutica*) in the Clyde Estuary, and the third on the occurrence of the Lesser Weever fish *Echiichthys vipera* in the Clyde Estuary. The report of *Caprella mutica* in the Clyde is particularly interesting, as the species is alien to Scottish waters.

THANKS AND ACKNOWLEDGEMENTS

We would like to thank all our contributors over the last three years, including those to the one issue of the journal that we were unable to edit due to pressures of other work (volume 24, part 3, 2005). That issue contained the proceedings of the conference on the Natural History of Loch Lomondside and the Trossachs that was organised by Roger Downie and edited by Richard Weddle. It is a pleasure to record that Roger Downie was one of Peter Meadows's honours students in the Department of Zoology in the 1960's, shortly after Peter joined the department as Lecturer in Zoology in 1963. It was Roger who, while President of the Glasgow Natural History Society, approached us about five years ago to take on the editorship of the journal, which we have done with much pleasure over a period of three years. Our own view is that this is the most appropriate length of time to undertake this onerous but very rewarding task. Thanks also to Norman Tait, who continues to provide the first rate final copy for the back and front colour covers of the journal. Our printers have been especially accommodating, and we sincerely thank Christopher Steward at Stirling Design and Print, Stirling Council, and Brian Watt and Lyn Aikman at Universities' Design and Print, Strathclyde and Glasgow Universities.

Our final thanks go to Dominic McCafferty the new editor, and to Morag MacKinnon who Peter also taught many years ago, for their most helpful support that has made the hand over of the editorship of the journal from us to Dominic both smooth and quick. We wish Dominic every success in handling the various burdens of the editorship, and hope to continue our contributions to the journal in the form of papers on Scottish environmental issues.

Azra Meadows and Peter Meadows. February 2007.

References

IPCC 2007. Contribution ofWorking Group I to the Fourth Assessment Report of the International Panel on Climate Change . Summary for Policymakers. Available at web site http://www.ipcc.ch/

Stern, N. 2007. *The Economics of Climate Change. The Stern Review.* Cambridge University Press.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 7-23.

THE INTERNATIONAL PANEL ON CLIMATE CHANGE , THE STERN REVIEW, AND SCOTLAND

Azra Meadows and Peter S Meadows
Division of Environmental and Evolutionary Biology,
Institute of Biomedical and Life Sciences,
University of Glasgow, G12 8QQ.
gbza31@udcf.gla.ac.uk

ABSTRACT

Climate change has been happening since the earliest history of the planet Earth, and has often been dramatic. Recent examples are the Medieval Warm Period, c. 950 to 1250 BP, and the Little Ice Age, c. 1500 to 1800 BP. However climate change, and especially global warming during the last 100 to 150 years, is now considered to have been largely caused by the activities of man. The outstanding work conducted by the International Panel on Climate Change (IPCC) since its formation in 1988, and the summaries presented in the Stern Review (Stern 2007), and many other works, now make this abundantly clear. They also emphasise the severity of the situation.

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average temperature and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Eleven of the last twelve years (1995-2006) rank among the 12 warmest years in the instrumental record of global surface temperature since 1850" IPCC (2007).

"There is still time to avoid the worst impacts of climate change, if we take strong action now. The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly." Stern (2007)

We review the current scenario, focussing on the most recent information available from the IPCC (IPCC, 2007) and the Stern Review (2007), and discuss the implications for Scotland. We firstly describe the global energy system and the nature of the greenhouse gases, and then consider the global climate system and its effects on global and local ecosystems. We then review the Stern Review's central questions and the global issues that the review raises, and consider the implications for developing and developed countries. This is followed by an assessment of the effects of climate change on the UK and in particular on Scotland and its economy. This latter includes a consideration of information available from Scottish Enterprise on employees in different industries, Scottish export performance, and sector profiles for Scotland's gross domestic profit, and how all of these will be affected by climate change. The final part of our paper briefly summarises renewable energy options for individual households and communities in Scotland. The appendix considers personal carbon footprints and carbon offsetting – including offsetting by planting trees. All of this is directly relevant to anyone living in Scotland.

THE BACKGROUND

"With hindsight, however, the potential rise in sea level caused by global warming over the next 50 years may be the most important factor in coastal zone development. The difficulty with global warming is the lack of precision in predictions, and the lack of agreement about how much of the potential warming is caused by man's activities as compared to natural long term perturbations in weather patterns" (Meadows & Meadows, 1998). This should now be reworded to read: "With hindsight, however, **global warming and** the potential rise in sea level caused by global warming over the next 50 years may be the most important factors threatening ***global*** development. The difficulty with global warming is the lack of precision in predictions, and the lack of agreement about how much of the potential warming is caused by man's activities as compared to natural long term perturbations in weather pattern".

Nine years after our 1998 article on "Mountains, rivers and the coastal zone in Asia: environmental management into the 21st century" from which the above quotation is taken (Meadows & Meadows, 1998), and five years after our subsequent article on "Climate Change. Its History and Future in Relation to Scotland's Landscape, People, and Economy" (Meadows & Meadows, 2002), the situation has become much more worrying. It is clear that the situation is now significantly worse than many scientists intuitively thought in the 1990's.

Our realisation of the worsening situation has been led by the International Panel on Climate Change (IPCC) and related organisations. The IPCC was established by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) in 1988 to assess the scientific technical and socio-economic background to climate change, the impacts of climate change, and the options available for adaptation to and mitigation of climate change effects. It does not undertake new research or monitor climate data, but produces its reports on the published literature. Since its establishment, the International Panel on Climate Change (IPCC) has issued a series of outstanding reports on climate change (cf Bruce *et al.*, 1996; Houghton *et al.*, 1996; Watson *et al.*, 1996; Ramaswamy *et al.* 2001; IPCC, 2005; IPCC, 2007). It is now finalising its Fourth Assessment Report on Climate Change in 2007. The dates for the release of the Fourth Assessment Report are as follows: Working Group I "The Physical Science Basis", release due 2nd Feb 2007; Working Group II "Impacts, Adaptation and Vulnerability", release 16th Feb 2007; Working Group III "Mitigation of Climate Change", release 4th May 2007.

As this paper goes to press, the IPCC 2nd Feb 2007 report, "Climate Change 2007: The Physical Science Basis. Summary for Policymakers" has been published on its web site (IPCC, 2007). The following are almost verbatim

quotations from the IPCC (2007) report and emphasis the extreme seriousness of the global climate change scenario.

- "Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture."
- "The understanding of anthropogenic warming and cooling influences on climate has improved since the Third IPCC Assessment Report (TAR) leading to a very high confidence (9 out of 10 chance) that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing[1] of + 1.6 to + 2.4 $W.m^{-2}$. The combined radiative forcing due to increases of carbon dioxide, methane and nitrous oxide is +2.07 to +2.53 $W.m^{-2}$, and its rate of increase during the industrial era is very likely to have been unprecedented in more than 10,000 years. The carbon dioxide radiative forcing increased by 20% from 1995 to 2005, the largest for any decade in the last 200 years."
- "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air temperature and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Eleven of the last twelve years (1995-2006) rank among the 12 warmest years in the instrumental record of global surface temperature since 1850."
- "At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and intensity of tropical cyclones."
- "Paleoclimate information supports the interpretation that the warmth of the last half century is unusual in at least the last 1300 years. The last time polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 metres of sea level rise."

NATURAL CLIMATE CHANGE

Climate change has occurred since the earth was first formed, with one of the first and arguably most important steps being the change from an essentially anaerobic atmosphere to an aerobic one, in which photosynthetic and other autotrophic organisms (autrotrophic microorganisms and multicellular plants) and heterotrophic organisms (heterotrophic microorganisms and multicellular animals) balanced each other, the first producing oxygen and using carbon dioxide, and the latter using oxygen and producing carbon dioxide. This change probably took place between 4000 and 3000 million years ago, with the age of the earth being about 4500 million years. Even within the last 2000 years, climate change has been significant, with widely varying global temperatures. Recent assessments (Figure 1) quantify the Medieval Warm Period from about 950 A.D. to 1250 A.D., and the Little Ice Age from about 1500 A.D. to about 1800 A.D., both of which had a dramatic effect on life in Europe at the time. The most dramatic change has been since the middle of the 19th century (Figure 2), with the fastest changes taking place from 1910 to 1940 and then again from 1970 to the present time. It is interesting to note however that the period between 1940 and 1970 had some of the coldest winters, with the sea freezing along parts of the Scottish coast in the winter of 1963. So the increase in temperature is not a regular one.

ENERGY RADIATED FROM THE EARTH INTO SPACE, AND THE GREENHOUS GASES

The way in which the earth receives energy from the sun and then re-radiates it into space, and the effects of greenhouse gases in altering this balance, are essentially quite straight forward. The sun, at a temperature of approximately 6000 °K, radiates energy into space at a wavelength of about 0.1 micron to about 2.4 micron with a peak in the visible spectrum at about 0.4 to 0.8 microns (Figure 3 left hand graph). The earth absorbs some of this energy, and then irradiates it back into space (Figure 3 right hand graph). Being a much colder body than the sun –its temperature is about 285 °K, the energy that the earth irradiates into space is of a much longer wavelength - from about 2 microns to more than 32 microns. Within this wavelength range, water, carbon dioxide and ozone block out some of the wavelengths, absorbing the radiation, so water, carbon dioxide and ozone are natural green house gases, because they maintain the earth at a higher temperature than it would otherwise be. This blanketing effect currently maintains the earth's temperature at 285 °K (12°C) rather than 250°K (-23°C) which it would otherwise be (Meadows & Campbell, 1988, p9), a difference of 35°K or 35°C. The absorption of radiation from the earth by these natural greenhouse gases leaves several radiation windows by which radiation from the earth can irradiate back into space as shown in the right hand graph of figure 3.

---

[1] The IPCC 2007 report defines radiative forcing as "a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In the IPCC 2007 report radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre ($W\ m^{-2}$)".

Figure 1. Constructed global temperature over the last 2000 years, based on ten different published reconstructions (Wikipedia, 2007).

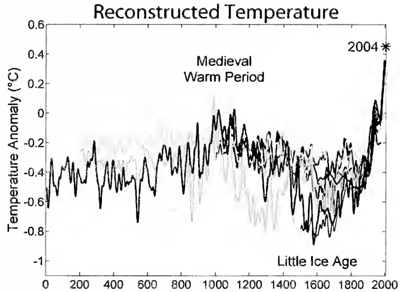
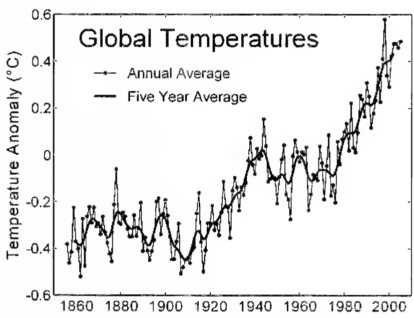


Figure 2., Change in the global average temperature over the last 150 years (Wikipedia Web site). The web site states that 'the instrumental record of global average temperatures was compiled by the Climatic Research Unit of the University of East Anglia and the Hadley Centre of the UK Meteorological Office. Data set TaveGL2v was used. The most recent documentation for this data set is Jones and Moberg (2003). This figure was originally prepared by Robert A. Rohde from publicly available data and is incoporated into the Global Warming Art project'.



Man-made greenhouse gases mimic the effect of water ozone and carbon dioxide in the atmosphere, and further reduce the amount of radiation that the earth is able to irradiate back into space (Table 1). Unfortunately, the man-made greenhouse gases are much more active than carbon dioxide in reducing this irradiation. Table 1 shows that the approximate effects in terms of their relative global warming potential (GWP) relative to carbon dioxide's global warming potential (GWP) of 1, are x3400, x7100 and x1600 for Trichlorfluoromethane (CFC11), Difluorodichloromethane (CFC12) and Difluorochloromethane (HCFC22), respectively.

More recent estimates (Stern, 2007) (Table 2), show similar effects, although the classification of gases is different to that in table 1, and is based on some of the six gases and groups of gases that are covered by the Kyoto Protocol. These six gases are Carbon dioxide, Methane, Nitrous oxide, Hydrofluorocarbons, perfluorocarbons, and Sulphur hexafluoride. The main sources of the greenhouse gases covered by the Kyoto Protocol. Carbon dioxide is present naturally in the atmosphere, and is derived from a number of sources including volcanic eruptions, and respiration by plants and animals. It is also produced by man burning of fossil fuels and by fuels used by aircraft and vehicles. Carbon dioxide is used by plants during photosynthesis and is also absorbed by the world's oceans. Methane derives from the anaerobic decay of animal and plant remains in the ecosystem, and from vertebrates in particular as they break wind during digestion. It is also produced by wetlands and rice paddies. Nitrous oxide is produced as a natural part of the nitrogen cycle in soil, and in freshwater and marine ecosystems. Anthropogenic sources include the production of nylon and the use of nitrogen fertilisers in agriculture. It is also released during the burning of fossil fuels and other organic substances. HFC's and PFC's are used in the refrigeration industry and also as aerosols. Sulphur hexaflouride is used in circuit breakers and in electric circuitry, in the gas-insulation of electric gear, in aerosols, and in sound insulation.

Figure 3. Distribution of radiation energy with wavelength for the sun (right hand graph) and the earth (left hand graph). Technically, the left hand graph (A) is radiation from a black body having the equivalent temperature of the sun of c. 6000°K, and the right hand graph (B) is radiation from a black body having the equivalent temperature of the earth of c. 285°K. The shaded areas in the right hand graph show the absorption of radiation in the earth's atmosphere by water (H_2O), ozone (O_3) and carbon dioxide (CO_2). (Harvey 1976; Meadows and Campbell, 1988).

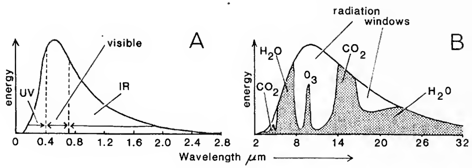


Table 1. Greenhouse gases their relative effect, concentrations in the atmosphere, current rate of change, and atmospheric lifetime. GWP : Global warming potential; ppmv: parts per million by volume; * carbon dioxide does not have a single lifetime because the uptake rates differ for different sink processes. Global warming potential is the predicted reduction in the amount of heat radiated from the earth produced by a particular gas, in relation to the reduction produced by carbon dioxide over the same time period. It is only a very approximate measure of the relative effect of a greenhouse gas, as errors of up to 35% are recognised (Department of the Environment ND; Houghton *et al.*, 1996, p. 21; Meadows & Meadows, 1998). CFC 11 = Trichlorfluoromethane. CFC 12 = Difluorodichloromethane (Freon 12). HCFC 22 = Difluorochloromethane (Freon 22).

Greenhouse gases	Approximate relative greenhouse effect (GWP)	Current average atmospheric concentration (ppmv) (1992)	Current rate of change (%pa)	Atmospheric lifetime (years)
Carbon Dioxide	1	355	1.8	50-200*
Methane	11	1.72	0.8	12
Nitrous Oxide	270	0.31	0.25	120
CFC 11	3400	0.00026	4	50
CFC 12	7100	0.00045	4	-
HCFC 22	1600	0.0001	-	12

Table 2. The Kyoto Greenhouse Gases carbon dioxide, methane, nitrous oxide, HFC's and PFC's. Lifetime in the atmosphere, 100 year global warming potential (GWP) and percentage of emissions in 2000, in carbon dioxide equivalents (Sterne, 2007, Table 8.1. Data from Ramaswamy *et al.*, (2001) and the World Resources Institute (2006). HFC's = hydrofluorocarbons. PFC's = perfluorocarbons. (Stern 2007)

	Lifetime in the atmosphere (years)	100 year global warming potential (GWP)	Percent emissions in 2000 (carbon dioxide equivalents)
Carbon Dioxide	5 - 200	1	77%
Methane	10	23	14%
Nitrous Oxide	115	296	8%
HFC's	1 – 250	10 – 12,000	0.5%
PFC's	> 2,500	> 5,500	0.2%
SF_6	3,200	22,200	1%

RECENT REPORTS ON GLOBAL WARMING. THE STERN REVIEW

All of the above means that climate change is here. It will have a progressively greater impact on all aspects of the planet Earth, and at a local level on Scottish life, landscape, biodiversity and wildlife. There is no doubt about this, although there is considerable discussion about the immediate and indirect causes and the potential long-term impact. The matter is globally of very great importance, and the recent publication of a series of major reports, is therefore timely. It enables us to review the current situation in a general context and then to focus on Scotland (Gallani *et al.*, 2006; Hewer, 2006; Stern, 2007).

The first two of these reports (Gallani et al., 2006; Hewer, 2006), were issued by the UK Met Office, based in Exeter, Devon. Hewer (2006) explores the interactions between climate change and energy management, and Gallani et al (2006) provide a scoping study on the impacts of climate change on the UK energy industry. Both reports have important implications for the UK and locally for Scotland.

The third of these reports (Stern, 2007) is the 'Stern Review on the Economics of Climate Change' which is already available on line from the HM treasury web site (www.hm-treasury.gov.uk) and now (January 2007) published by Cambridge University Press (ISBN 0-521-70080-9) (Stern 2007). The review is massive, being almost 700 pages long (600 pages in the web site version). Its six parts cover almost all that is currently known about climate change, and has as its backdrop the three volume work on Climate Change published a decade ago for the Intergovernmental Panel on Climate Change - IPPC (Bruce *et al.*, 1996; Houghton *et al.*, 1996; Watson *et al.*, 1996).

Part One of the Stern Review (Stern, 2007 pp 1-61, web site version pp 1-54) provides a general background to climate change and to its economic implications. Part Two (Stern, 2007 pp 63-190, web site version pp 55-167) considers the impacts of climate change on growth and development, including the effects around the world, and costs for developing countries. It also draws attention to the current situation regarding economic modelling. Part Three (Stern, 2007 pp 191-348, web site version pp 168-307) discusses the economics and costs of stabilising climate change, together with an analysis of macroeconomic models and competitiveness. An annex gives statistics for one hundred and twenty three production sectors ranging from 'private households with employed persons' to 'fishing' and 'carpets and rugs', and overviews a goal for a climate change policy with ten key messages (Stern, 2007, web site version p 284). Part Four (Stern, 2007 pp 349-454, web site version pp 308-402) on policy responses for mitigation considers how markets can be harnessed to reduce emissions of greenhouse gases, and how carbon pricing and emission markets operate in practice. It follows this by considering ways in which technological innovation can be accelerated. Part Five (Stern, 2007 pp 455-506, web site version pp 403-448) discusses policy responses for adaptation, including the economics of adaptation, problems and potential solutions in the developed world, and sustainable development. Part Six (Stern, 2007 pp 507-644, pp web site version pp 449-575) gives a detailed overview of the need for and mechanisms of achieving international collective action. This includes developing a price for carbon that is applicable on a global scale and ways of moving towards a global low carbon economy. It then considers how to encourage cooperation on international technology transfer, and how to reverse emissions from changes in land use. The remaining pages of the Stern Review (Stern 2007, pp 645-692) are taken up with abbreviations and acronymns, a postscript and technical annexe to it, and the index.

THE THREE KEY THEMES OF THE STERN REVIEW

The Stern Review (Stern, 2007) points out that climate change is a global problem that needs to be tackled globally. It draws our attention to three key features, or themes, that are used throughout the review and which should also influence our thinking more generally – uncertainty, risk and equity. There is no doubt that climate change induced by man's actions has been occurring since the early 19[th] century. But there is uncertainty about the time scale geographical location and degree of its effects in the 21[st] century and beyond. There is however a broad consensus that the impacts are likely to be very large. The Stern review considers the economics of the management of the very large risks that are likely to be involved. The risks are now beginning to be given probabilities. The probabilities relate to two conceptual climate change links. The first link is between emissions of climate change gases and resultant changes in the global climate system, and the second link is between changes in the global climate system and changes in the natural environment. The Stern Review sees equity between the current generation and future generations as being a moral imperative, with especial importance to poor communities – those in developing countries. This requires an ethical perspective to be applied when using economic models that propose changes to the way in which we handle ourselves, use our consumables, and change our environment.

THE GLOBAL CLIMATE SYSTEM AND ITS EFFECTS ON GLOBAL AND LOCAL ECOSYSTEMS

The global climate system and its effects on global and local ecosystems and human populations is made up of a complex web of interacting processes and feedbacks that have been discussed by a number of authors (c.f. Meadows & Meadows, 1998, 2002; Stern 2007).

Stern (2007) provides a diagram of this complex web that we have modified slightly (Figure 4). Physical changes in the climate include rising mean surface temperatures, rising sea levels, changes in the variability and seasonality of rainfall, changing patterns of natural climate variability, and the melting of ice sheets, sea ice and land glaciers. Stern (2007) indicates that these physical changes have two feedback processes associated with them. The first feedback process (lower feedback in figure 4) suggests that there is a potential reduction in the efficiency of the land and sea to absorb carbon dioxide together with a tendency for an increase in the natural release of methane to take place. These lead to rises in the concentrations of greenhouse gases, which in turn lead to changes in the global energy balance. The second feedback process includes changes in cloud distribution and the water content of the atmosphere (upper feedback in figure 4), which together with changes in the sunlight reflected by sea ice, produce a change in the energy balance of the atmosphere, sometimes called radiative forcing. The radiative forcing then causes increase in the temperature of the atmosphere, leading to rising global surface temperatures, and on a longer time scale causes rising ocean temperatures in turn leading to rising sea levels. Lastly, changes in land use and increasing greenhouse gas emissions (left hand side of figure 4) themselves produce the rising concentrations of greenhouse gases. The whole series of interacting processes is complicated, and even now not fully understood.

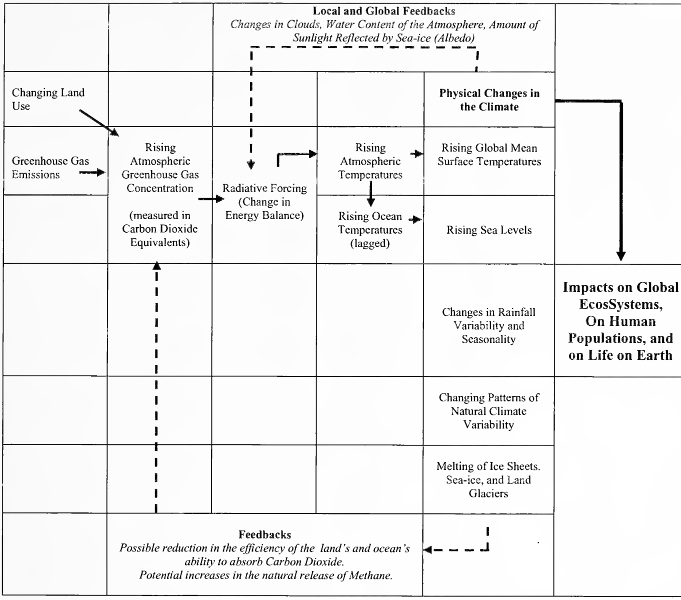
Meadows and Meadows (1998) (Figure5) provide an alternative view by considering the effects of climate change on three distinct ecosystems – mountains, rivers and the coastal zone, and dividing effects into natural and human impacts. Natural and human impacts interact through a series of processes with outputs, leading a consideration of how environmental management relates to and can ameliorate the effects of climate change. All of these have a direct bearing on Scotland, whose landscape is defined by mountains, rivers and the coastal zone.

In mountain ecosystems, natural impacts include global warming early melting of snow and glaciers, and resultant increase in the weathering of rocks causes increased water discharge and soil erosion. Human impact in mountain ecosystems consists largely of deforestation, leading to increased soil erosion. Natural and human impacts can be ameliorated by reducing the build-up of greenhouse gases, by reforestation, and by generally improving land management.

In river ecosystems, the processes involved in natural and human impacts include flooding, water logging, and industrial and domestic pollution. These processes have as outputs increased water discharge, changes in or abandonment of agricultural land, pollutant discharge, and changes in water quality. Environmental management that will ameliorate the effects of climate change include improved pollution control, and the development of flood control defences such as dams, barrages, dykes and outfall drains for runoff water.

In coastal zone ecosystems the processes involved in natural and human impacts are probably most marked. They consist of sea level rise, increased likelihood of hurricanes and cyclones, industrial and domestic pollution, and coastal habitat degradation. Outputs include flooding of low lying coastlines, losses of coastal habitats, loss of human life, changes in nearshore fisheries and loss of nursery grounds for fish, and eutrophication. Environmental management that will ameliorate the effects of climate change include improving coastal defences, increased use of predictive weather models and advanced satellite systems, managed resource exploitation, and conservation of coastal ecosystems.

Figure 4. Greenhouse Gases and Climate Change. Links and feedback systems (Modified from Stern, 2007, figure 1.4)



CENTRAL QUESTIONS POSED BY THE STERN REVIEW

There are a number of central questions that need to be addressed, and these have been eloquently listed by the Stern Review (Stern 2007, Introduction). We reproduce them with our own additions as follows.

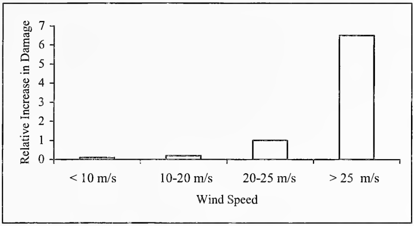
- What is our understanding of the risks of the impacts of climate change to human communities, animal communities and plant communities, and the costs of these impacts?
- Which peoples in which countries are most likely to be affected by these risks?
- Which ecosystems in which countries are most likely to be affected by these risks?
- What options are available for reducing emissions of greenhouse gases?
- How much are the options available for reducing emissions of greenhouse gases likely to cost?
- What implications do these options and their costs have for the choice of paths that will ensure stabilisation of the world?
- What economic opportunities are created by actions aimed at reducing emissions of greenhouse gases?
- What economic opportunities are created by the development and application of novel technologies to the reduction of greenhouse gases?
- What are the effects of the development and application of novel technologies to the reduction of greenhouse gases likely to have on biodiversity and ecosystems on a global scale?
- What incentive structures and policies for mitigating climate change will be most effective, efficient and equitable?
- What implications do the incentive structures and policies for mitigating climate change have for public finances?
- What approaches for adaptation to climate change are appropriate, and how should they be financed?
- How can approaches to both mitigation of and adaptation to climate change work at an international level?

Many of these questions cannot be properly answered at the present time, either on a global or at a country level. However based on the Stern Review the rest of this article draws attention to some of the issues that need to be addressed.

Figure 5. Natural and human impacts on global ecosystems in relation to climate change. The table has been divided into mountain, river and coastal ecosystems (Modified from Meadows & Meadows, 1998). The last column indicates what broad categories of environmental management are needed to ameliorate the effects of climate change. All of these are important for Scotland.

TYPE OF ENVIRONMENT	IMPACT	PROCESS	OUTPUT	ENVIRONMENTAL MANAGEMENT AND CLIMATE CHANGE
Mountain Ecosystems	Natural impact.	Global warming, melting of glaciers, weathering of rocks.	Water discharge, soil erosion.	Prevention of build-up of greenhouse gases.
	Human impact.	Deforestation, erosion.	Soil erosion, silting.	Reforestation, managed land use.
River Ecosystems	Natural impact.	Flooding.	Soil, particulates, salts, water discharge.	Flood control defences, dams, barrages, dykes.
	Human impact.	Water logging, desertification salinisation.	Abandoned agricultural land.	Construction of outfall drains.
		Industrial, domestic pollution.	Pollutant discharge, water quality.	Pollution control.
Coastal Zone Ecosystems	Natural impact.	Global warming, sea level rise. Hurricanes, cyclones.	Flooding of low lying coastlines. Loss of human life, habitat.	Coastal defences. Weather predictive models, satellites.
	Human impact.	Industrial and domestic pollution.	Decline in fisheries. Eutrophication.	Pollution monitoring.
		Over-exploitation of natural resources.	Depletion of natural resources.	Managed resource utilisation.
		Habitat degradation.	Loss of nursery grounds for fish.	Conservation, protection.

Figure 6. Increase of damage caused by increase in wind speed. This is a cubic function, as wind strength increases, damage increases by three . (Stern, 2007, p92)



GLOBAL ISSUES RAISED BY THE STERN REVIEW

Some of the predictions of possible climate impacts raised by the data quoted in the Stern Review are extremely worrying. If they occur they will undoubtedly have very significant impacts on the way we live in Scotland, and the way the world copes with the rapidly worsening scenario. For example, predicted increases in wind speed have a threefold impact on building damage (Figure 6). We summarise these predictions almost verbatim from table 3.1 of the Stern Review (Stern, 2007, chapter 3, pages 66 to 67), in terms of the impacts on water, food, health, land, the environment, and abrupt and large scale impacts. The temperatures are increases from pre-industrial levels.

The Stern Review (Stern, 2007, chapter 3, pages 66 to 67) divides the effects of climate change into impacts on water, food, health, land and the environment. The review also considers abrupt and large scale impacts. For each of these categories, five temperature categories are defined, 0.5 - 1.5 °C, 1.5 - 2.5 °C, 1.5 - 2.5 °C, 2.5 - 3.5 °C, 3.5 - 4.5 °C, and 4.5 - 5.5 °C. There is some uncertainty in the impacts quoted, which become more uncertain at the progressively greater temperatures. The number of people affected in each category and within each temperature range have been calculated assuming the GDP information provided by the Intergovernmental Panel on Climate Change. The categories of impacts within the temperature ranges quoted are as follows.

- ***Impacts on Water***

0.5 - 1.5 °C

The small glaciers in the Andes in South America are already disappearing, which will threaten water supplies to about 50 million people. It is also likely to have significant effects on food exported from these countries to European including Scottish markets. Glaciers in the Himalayan range of mountains are already retreating, and have been doing so for at least thirty years (cf Shroder & Bishop, 1999 figure 7, Batura Glacier).

In vulnerable regions such as the Mediterranean and Southern Africa – especially sub Saharan Africa, there will be a 20% to 30% decrease in the availability of water from present levels.

2.5 - 3.5 °C

There will be serious droughts in southern Europe approximately every ten years. One to four billion people will suffer water shortages, while one to five billion people will experience more water shortage which in turn will increase the risk to food production.

3.5 - 4.5 °C

Thirty to fifty percent decreases in water availability may potentially occur in the Mediterranean region and in Southern Africa – especially sub Saharan Africa.

4.5 - 5.5 °C

There is a likelihood of the major glaciers in the Himalayan mountain range disappearing completely, thus threatening one quarter of China's population and populations of many millions in Pakistan and India.

- ***Impacts on Food***

0.5 - 1.5 °C

There will be modest increases in cereal crop yields in temperate regions. This is likely to include Scotland.

1.5 - 2.5 °C

Sharp decreases in the yields of crops in tropical countries will occur. This is predicted to be a five to ten percent decrease in Africa.

2.5 - 3.5 °C

Agricultural yields in high latitudes are likely to peak. This may include or affect Scotland. An additional 150 to 550 million people, especially in Africa and parts of the Indian subcontinent will be at risk from hunger if carbon fertilisation (when plants soak up carbon dioxide for the atmosphere) is weak.
3.5 - 4.5 °C
Agricultural yields will decline by fifteen to thirty five percent in Africa, and may disappear completely from some areas such as parts of Australia.
4.5 - 5.5 °C
The continued increase in ocean acidity caused by increased levels of dissolved carbon dioxide may seriously disrupt marine ecosystems, thus affecting fish stocks.

- ***Impacts on Health***

0.5 - 1.5 °C
There is likely to be a reduction in winter mortality caused by cold weather in higher latitudes including Northern Europe and the USA. This will also have an effect in Scotland, although increasing wet winter weather such as that which occurred in autumn 2006 may reduce this effect (in Glasgow November 2006 was the wettest November since records began in 1914). Globally, at least 300,000 people per year will die of climate related diseases including diarrhoea, malaria, and malnutrition.
1.5 - 2.5 °C
Forty to sixty million more people will be exposed to malaria in Africa, and this is likely to spread to European countries, including the United Kingdom and specifically Scotland.
2.5 - 3.5 °C
One to three million more people will die from malnutrition if carbon fertilisation is weak.
3.5 - 4.5 °C
Up to eighty million more people in Africa will be exposed to malaria.
4.5 - 5.5 °C
Unknown on present estimates.

- ***Impacts on Land***

0.5 - 1.5 °C
The thawing of permafrost in parts of Canada and Russia is already damaging buildings. River and coastal flooding is already occurring in low-lying areas, and has had major adverse environmental impacts in Scotland. Plans are already being considered to increase the size of the Thames Barrier. When instituted in the 1980's the Thames Barrier was raised approximately once every two years. In 2003 it was raised nineteen times.
1.5 - 2.5 °C
Up to ten million more people are likely to be affected annually by coastal and river flooding. This will have further deleterious impact in Scotland.
2.5 - 3.5 °C
Coastal flooding caused by sea level rise will increase, and up to ten million more people are likely to be affected.
3.5 - 4.5 °C
Up to 170 million people will be affected by coastal flooding each year.
4.5 - 5.5 °C
Coastal flooding will submerge small low lying islands in the Pacific, and parts of Florida, and major cities including London, New York and Tokyo will be under major flooding threats or actualities.

- ***Impacts on the Environment***

0.5 - 1.5 °C
At least ten percent of all land species may be under threat. Up to fifty percent bleaching of coral reefs such as those on the Great Barrier Reef is already taking place.
1.5 - 2.5 °C
Fifteen to forty percent of land species may be under threat. There is a high risk of the total extinction of a number of Arctic and Antarctic species. In the Arctic, Polar Bears and Caribou are at high risk of total extinction.
2.5 - 3.5 °C
There may be the onset of the collapse of the Amazon rain forest. Twenty to fifty percent of species may face extinction. These include twenty five to sixty percent of mammals, thirty to forty percent of birds, and fifteen to seventy percent of butterflies in South Africa.
3.5 - 4.5 °C
Loss of about fifty percent of the Arctic tundra. Approximately half the world's nature reserves cannot fulfil their objectives.
4.5 - 5.5 °C
Unknown on present estimates, but extreme effects are almost certain to occur.

- ***Abrupt and Large Scale Impacts***

0.5 - 1.5 °C
The Atlantic thermocline circulation is beginning to weaken. The warm North Atlantic Drift current which maintains the relatively warm climate in western Europe, the UK and especially in northwest Scotland, has

already weakened significantly, and part of it stopped completely for ten days in November 2004. If the current remains as weak as it currently is, the temperature of the UK and Scotland may drop by as much as 1°C, not increase.

1.5 - 2.5 °C

The Greenland Ice Cap may begin melting irreversibly, which will accelerate sea level rise. This may lead to a seven metre rise in global sea level.

2.5 - 3.5 °C

There will be a rising risk of major changes to atmospheric circulation patterns and the major monsoonal systems in Asia.

3.5 - 4.5 °C

The collapse of the Antarctic Ice Sheet and of the Antarctic thermohaline circulation become more probable.

4.5 - 5.5 °C

There will be an increase in the abrupt and large scale impacts already listed.

The point is also made by the review, that if greenhouse gas emissions continue to increase unchecked, the global temperature is likely to increase by 5°C or more, which will have catastrophic implications for us all. This is "likely to lead to major disruption and large-scale movement of population". The review also states that "such socially 'contingent effects' could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience".

IMPLICATIONS OF CLIMATE CHANGE FOR DEVELOPMENT IN DEVELOPING COUNTRIES.

Key messages identified by the Stern Review (Stern Review 2007, ch 4) for the development of developing countries during climate change are as follows. Firstly, climate change poses a very significant threat for many developing countries. This is because of their geographical location, their dependence on agriculture at an often very basic level, and their low incomes. Secondly, many countries are already finding it almost impossible to cope with their current climate. This is clearly so for Sub Saharan countries, and is our own experience in many rural parts of Pakistan, where outside the major cities very isolated rural communities live in extreme poverty in mountain, desert and coastal areas.

The members of these rural communities have low or non-existent incomes Here there are major threats from increasing prevalence of tropical diseases – for example cholera epidemics, from floods caused by heavy rains and subsequent hillside erosion, and from tropical storms and cyclones in coastal areas. As these impacts become more serious, there will be major migrations of rural communities, and we have already observed this on a small scale in the very isolated parts of the coastal zone in Sindh Province, Pakistan during 2006.

The Stern Review estimates that the cost of this may be a nine to thirteen percent loss in GDP by 2100. This is a major threat which needs to be addressed now, otherwise it will lead to major problems not only for the poorer developing countries but for the developed countries that trade with them. There needs to be an immediate increased focus on encouraging growth and poverty alleviation in line with the eight United Nations Millennium Development Goals. These goals, which were agreed on by 189 countries in 2000, with a target date of 2015 for their achievement, are as follows.

- Halve extreme poverty and hunger.
- Achieve universal primary education.
- Empower women and promote equality between women and men.
- Reduce under five child mortality by two thirds.
- Reduce maternal mortality by three quarters.
- Reverse the spread of diseases, especially HIV/AIDS and malaria.
- Ensure environmental sustainability.
- Create a global partnership for development, with targets for aid, trade and debt relief.

In our view, these will be extremely difficult to achieve by the year 2015, even without climate change. So the problem of development in developing countries requires top priority by the developed countries. If it does not have this priority, not only will many people in developing countries suffer extreme hardship and die, but many of the people in developed countries including in Scotland will themselves suffer as feedback from developing countries in terms of lack of trade and increase in tropical diseases takes place.

COSTS OF CLIMATE CHANGE FOR DEVELOPED COUNTRIES

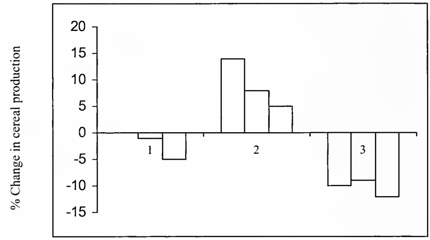
The costs of climate change in developed countries such as the European Union and its constituent countries is potentially large. The Stern Review (Stern Review, 2007 Ch 5) suggests that there will be some positive effects in the initial stages of global warming, but these will become negative as higher temperatures develop from about 2050 onwards. During these initial stages the effects on agriculture, and specifically on cereal production, will probably be positive - compared with the immediate negative impact in developing countries and an immediate negative impact globally (Figure 7).

The Stern Review (Stern 2007) identifies developed countries situated at higher latitudes, such Canada, Scandinavia and Russia, and to a lesser degree Scotland, as benefiting initially. Net benefits may accrue at

temperature increases of 2 to 3 degrees, with better agricultural yields (Figure 7), warmer winters with smaller heating costs, and potentially increased revenue from tourism. However, if one considers Scotland specifically, better agricultural yields in terms of cereal crops will mean major changes from sheep farming currently practised at higher altitudes, and so the environment will change, which in turn may affect tourism. Tourists may prefer to see traditional shepherding of sheep with dogs rather than intensive cereal production with modern combined harvesters. These points are all unpredictable, but one should be aware of them.

Overall, there will be an initial balance between gains and losses, with the losses predominating as time goes on and temperatures increase beyond 2 degrees. Figures quoted by the Stern Review (Stern Review 2007 pp138) suggest that in the United States of America, there will be changes of plus or minus one percent of GDP (Gross Domestic Profit), but a decline in GDP as temperatures go above an increase of 2 degrees. This will be largely caused by an increase in extreme weather conditions (c.f. Figure 6), and this is already beginning to take place in Scotland. In the United States of America, damage from hurricanes and storms will increase dramatically. An increase of five to 10 percent is likely to double the annual cost of repairing storm damage, leading to a loss of approximately 0.13% in GDP on an annual basis. Here, as in developing countries, the most vulnerable sector of the population will be the very poor.

Figure 7. Percentage changes in cereal production on a global scale (1), in developed countries (2), and developing countries (3), based on a doubling of the levels of carbon dioxide which will lead to a global increase in temperature of about 3°C. Figure modified from Stern (2007, p 83), data from Rozenzweig and Parry (1994) and analysed by Parry *et al.*, (2005). Simulations were obtained from three climate simulation models (the three bars in each of 1, 2, and 3) used by GISS (the NASA Goddard Institute for Space Studies), GFDL (the Geophysical Fluid Dynamics Laboratory, Princeton University) and the UK Meteorological Office Hadley Centre.



The Stern Review (Stern, 2007, pp 144–147) lists in detail the regional impacts of climate change for the United States of America, Canada, the United Kingdom, Mainland Europe including EU 27, Russia, Japan and Australia. We quote the negative and positive regional impacts for the United Kingdom (Table 6) given by Stern (2007), and identify those impacts which will affect the whole of the United Kingdom, or which will affect England Scotland and Wales differentially. The most important difference between Scotland on the one hand and England and Wales on the other is that Scotland will probably be less affected by drought.

SCOTLAND'S ECONOMY

The economy of Scotland is like almost all other countries, likely to become progressively more impacted by climate change. This will probably involve warmer wetter winters, an increased frequency of extreme weather conditions, and an increased frequency of river flooding and coastal zone flooding by the sea. The effects on the Scottish economy have not been fully assessed yet, but a consideration of the information available from the Scottish Enterprise web site provides a number of statistics that should be considered.

Scottish Enterprise lists a number of current statistics on employees in different industries, exports and sector profiles that allow a consideration of the potential effects of climate change to be assessed, at least at a very preliminary level (Scottish Enterprise. 2006 web site). Out of a current total work force of 2,343,600 in 2006 (Table 7), the largest number of employees are in Retail & Wholesale (354,100), Health & Social Work (349,800), Real Estate & Business Services (309,300), and Manufacturing (227,100). Climate change will affect all of these. The retail and wholesale industry will be affected by adverse changes in southern European countries and developing countries in Asia and Africa. Health and Social work personnel will have to deal with changing patterns of illness including the progressive increase in the occurrences of tropical disease. The Real Estate and Business sector is already facing difficulties in selling property that is sited in flood-prone areas, and this will get worse. The manufacturing sector will need to take account of changes in the availability of manufactured goods and raw materials coming from developing countries that progressively change with climate change. The agriculture, forestry and fisheries sector, although only employing 30,800 people, is probably the sector that will see the greatest change as climate change develops. Clearly there will be changes in agriculture

with the probability of more cereal crops, forestry will need careful consideration because of the effects on hillside stability and on local flora and fauna, and fisheries are already changing – often in unpredictable ways including new records of more southern species of fish and plankton in Scottish waters.

Table 6. Regional impacts of climate change applicable to the United Kingdom (Stern, 2007 pp145), with the current authors breakdown of the impacts by region (England, Scotland, Wales).

		United Kingdom as a whole	England	Scotland	Wales
Negative Impacts	Infrastructure damage from coastal and river floods, and storms	Yes	Yes	Yes	Yes
	Droughts. Constraints on water usage especially in summer	Yes	Yes	Not very significant	Yes
	Warmer summers leading to high energy needs for air conditioning	Yes	Yes	Yes	Yes
Positive Impacts	Milder winters leading to lower energy needs for heating	Yes	Probably YES??	Yes	Yes
	Initial increases in agricultural productivity – but depends on water	Yes	Yes	Probably	Probably

Table7. Number of employees in different industries in Scotland. (Scottish Enterprise. 2006 web site).

Industry	**Employees**
Agriculture, Forestry & Fishing	30,800
Mining/Quarrying Industries	23,900
Electricity, Gas and Water Supply (Utilities)	16,000
Manufacturing	227,100
Construction	134,300
Retail & Wholesale	354,100
Hotels & Catering	174,200
Transport, Storage and Communication	129,000
Financial Services	113,700
Real Estate & Business Services	309,300
Public Administration	158,500
Education	193,600
Health & Social Work	349,800
Other Services	129,600
Total Employee Jobs, March 2006	2,343,600

Scottish export performance, export destinations and the export industries, together with the regions of the world to which Scotland exports its goods will be heavily impacted by the projected climate changes itemised in the Stern Review (Stern, 2007), and listed above. The Scottish Enterprise web site provides invaluable current information on these export industries (Scottish Executive, 2006 web site) (Table 8, 9). The total value of Scotland's exports excluding oil and gas were estimated at £17,490 million for 2004. This was made up of £12,285 million in the manufactured production and construction sectors, £4,615 million Service sector, and

£590 million in the primary sector. The five top export destinations were the USA, the Netherlands, Germany France and Spain, and the top five export areas by geographical destination region were the EU 25 now EU 27 (the 27 member states making up the European Union including the two 2007 entrants – Bulgaria and Romania), North America, the rest of Europe outside the EU 27, Asia, and the Middle East.

All these countries and geographical regions will be progressively affected by more coastal flooding, and so civil engineering solutions will be needed, and many Civil Engineering companies and University departments are becoming involved. The southern parts of the USA, France and Spain will become more tropical, which will need to be included into export planning over the coming years. Renewable energy devices will be needed, especially those using solar and wind energy. This is already being developed by Scottish companies, and solar and wind energy devices for domestic housing are already on sale in B & Q warehouses in Glasgow. Tropical diseases and malnutrition in many parts of Africa and Asia will also need to be addressed in terms of export of equipment and expertise. The five top export industries are currently Food and Beverages (including distilled potable beverages i.e. Whisky), Office Machinery/Computers, Business Services, Chemicals (including Petroleum Products), and Radio, TV, Communications and Electronic Equipment. Here, it is likely that food, computers, chemicals, and communications will have significant potential for export to countries and geographical regions listed in table 8. The requirements of these countries and geographical regions will progressively change as temperatures increase and weather patterns become altered, and will need to be integrated with the information in table 9 to provide a long-term sustainable and flexible plan for Scotland.

Table 8. Scottish export performance, top five export destinations, top five export industries, and exports by destination region (Scottish Executive, 2006 web site).

Scottish Export Performance 2004	**£million**
Manufactured/production/construction	12,285
Service sector	4,615
Primary sector	590

Top five export destinations	**£million**	**Top five export industries**	**£million**
USA	2,610	Food and Beverages (including distilled potable beverages)	2,840 (2,355)
Netherlands	1,645	Office Machinery/Computers	1,785
Germany	1,600	Business Services	1,755
France	1,165	Chemicals (including Petroleum Products)	1,650
Spain	775	Radio/TV/Communications equipment	1,380

Exports by destination region	**£million**
EU 25	8,825
Total North America	2,890
Rest of Europe	1,300
Asia	2,050
Middle East	635
Central & South America	435
Australasia	365
Africa	240
Other	745

Table 9. Sector profiles for Scotland. Gross Domestic Product (GDP) at basic prices Gross Value Added (GVA) in £million (Scottish Executive, 2006 web site).

GDP at basic prices (GVA) (£million)	2004	2003
Aerospace	470	370
Chemical/Pharmaceutical	1,030	960
Construetion	4,700	4.400
Creative industries	4,045	3,235
Electronics	2,124	2,205
Food & Drink Manufacture (including whisky/spirits)	2,707 (1,230)	2,355 (1,050)
Retail	4,800	4,600
Shipbuilding	260	150
Textiles	350	395
Tourism-related industries	3,500	3,100

RENEWABLE ENERGY OPTIONS FOR INDIVIDUAL HOUSEHOLDS AND COMMUNITIES IN SCOTLAND

A number of countries have invested in the use of renewable energy resources, which are pollution free and do not emit **CO_2 for example wind turbines, solar panels and biofuels.** Special grants are available in Scotland to individual households and communities to purchase alternate energy devices such as solar panels and wind turbines. The Scottish Communities and Householders Renewables Initiatives (SCHRI) provide free advice and grants for solar panels to heat water. The solar panels are installed on rooftops and harvest the solar energy during daylight and transfer the heat to the water in the hotwater tank. They cost from £2,000 to £3,000.

The Scottish Executive has recently backed a pilot launch of rooftop wind turbines at five primary schools in Fife in 2004. The Edinburgh Company *Renewable Devices Ltd.* developed the 'swift turbine' which can be installed on rooftops and can directly power the building without feeding into a grid. The generating capacity of each turbine is 4000kW hours of green electricity per year and this saves 1,720kg of carbon dioxide. For grant applications to install solar panels and wind turbines logon to www.est.org.uk/schro.

SUMMARY OF CONCLUSIONS OF THE STERN REVIEW

We list verbatim the highlights from the Stern Review's Summary of Conclusions (Stern Review, 2007 pp xv – xix) with our additional comments based on the Stern Review's summary of conclusions.

Many of these are applicable at a personal level, all are necessary at a national and international level. In particular, if developing countries are not helped, we will all suffer huge losses in living standards.

- **There is still time to avoid the worst impacts of climate change, if we take strong action now.**

This needs action now on water resources, health, the environment and food production. If we do not act now, we will lose about 5% of global GDP per annum (GDP = Gross Domestic Product). This could rise to 20% of GDP per annum.

- **Climate change could have very serious impacts on growth and development.**

Unless we significantly reduce global greenhouse gas emissions now, there is a 50% chance of global temperatures rising 5°C or more in the longer term over the coming century..

- **The costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly.**

To avoid the worst aspects of climate change, global greenhouse gases must be stabilised at between 450 and 550 ppm of carbon dioxide equivalents. 2007 levels are about 430 ppm and rising at more than 2 ppm per annum. Stabilising levels in the range 450 to 550 ppm means reducing global greenhouse gases to at least 75% of current levels by 2050 – less than 45 years from now.

- **Action on climate change is required across all countries, and it need not cap the aspirations for growth of rich and poor countries.**

Both developed and developing countries need to reduce their production of greenhouse gases. This is essential. One without the other will not work.

- **A range of options exists to cut emissions; strong, deliberate policy action is needed to motivate their take-up.**

Increased efficiency, changes in demand, and use of clean power, heat, and transport technology will reduce greenhouse gas emissions. Everyone can take part in this. In addition, at an industrial level, the power sector globally will need to be more than 60% decarbonised by 2050 for the value of 550 ppm carbon dioxide equivalents to be met. Because coal will continue to be an important source of energy during this period, novel carbon capture and carbon storage technologies will need to be developed.

- **Climate change demands an international response, based on a shared understanding of long-term goals and agreement on frameworks for action.**

The European Union, the US state of California, and China apparently have the most ambitious policies to reduce greenhouse gases. These policies need to be extended to other countries and groups of countries. The Stern Review identifies the key elements in this process as being: (1) Emissions Trading. Expansion and linking between countries of current schemes. (2) Technology Cooperation. Energy research and development should be doubled globally. (3). Action to Reduce Deforestation. Reducing deforestation is a very cost effective method of reducing greenhouse gas emissions. (4). Adaptation. Developmental policy for and in developing countries must take account of the effects of climate change, and pledges of aid from developed countries to developing countries should be honoured. The Stern Review also points to the need for more research on new crop varieties that will be resilient to drought and flood conditions.

CONCLUSION

In this editorial we have covered climate change as an evolving scenario by reviewing a number of points in the IPCC 2007 report and the 2007 Stern Review. It is a stark reality that climate change is already affecting the present generation, and that climate change will do considerably more damage to future generations. There are a number of ways in which human impacts that contribute to global warming can be reduced. These need to be adopted now, by individuals, communities, businesses, organisations and nations.

Finally, we cannot do better than quote the Stern Review (2007 pp.xviii):

"Each country, however large, is just a part of the problem. It is essential to create a shared international vision of long term goals, and to build international frameworks that will help each country to play its part in meeting common goals."

REFERENCES

Bruce, J.P., Lee, H., Haites, E.F. (eds) (1996) *Climate change 1995.Economic and Social Dimensions of Climate Change.* Contribution of working group III to the second assessment report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.

Department of the Environment. n.d. (c.1996 - authors). *Global Climate Change.* pp 1-24. 3rd Edtn.

Harvey, J.G. 1976. *Atmosphere and Ocean.* Artemis, Sussex.

Houghton, J.T., L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell (eds) (1996) *Climate change 1995.The Science of Climate Change.* Contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.

IPCC, 2005. IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the International Panel on Climate Change (Metz, B., Davidson, O., de Coninck, H.C., Loos, >,m and Meyer, L.A. (Eds). Cambridge University Press, Cambridge.

IPCC 2007. Contribution ofWorking Group I to the Fourth Assessment Report of the International Panel on Climate Change . Summary for Policymakers. Available at web site http://www.ipcc.ch/

Jones, P.D. & Moberg, A. 2003. Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001. *Journal of Climate*, 16, 206-223.

Meadows, A., & Meadows, P. S. 1998. Mountains, rivers and the coastal zone in Asia: environmental management into the 21st century. Shiga University, Japan. International Symposium. Symposium volume. In: Integrated Environmental Management: Development, Information, and Education in the Asian-Pacific Region. Chapter 4. pp 49-76. Eds. Itakura, Y., Eades, J.S., D'Itri, F.M., Kawashima, M., Endoh, S. & Kitamura, H. Lewis Publishers, Boca Raton.

Meadows, A., & Meadows, P.S. 2002. Climate Change. Its History and Future in Relation to Scotland's Landscape, People, and Economy. The Glasgow Naturalist, **24(1)**: 15-22.

Meadows, P.S. & Campbell, J.I. 1988. *An Introduction to Marine Science.* 2nd Edtn. Blackie, Glasgow and London.

Parry, M.I., Rosenzweig, C., & Livermore, M. 2005. Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society of London* B, **360**, 2125-2136.

Ramaswamy, V. Boucher, J, Haigh, D. Hauglustaine, J. Haywood, G., Myhre, T., Shi, G., & Solomon, S. 2001. Radiative forcing of climate change. Chapter 6 in Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (J.Houghton et al (eds)). Cambridge University Press, Cambridge.

Rosenzweig, C., & Parry, M.L. 1994. Potential impact of climate change on world food supply. *Nature* **367**, 133-138.

Scottish Executive. 2006 web site. <www.scottish-enterprise.com/sedotcom_home/sig.htm>

Shroder, , J.F., & Bishop, M.P. 1999. Indus to the sea: evolution of the system and Himalayan Geomorphology. Pp 231 – 248 in *The Indus River: Biodiversity, Resources, Humankind.* Edit. A. Meadows and P. .Meadows. Oxford University Press, Karachi, Pakistan.

Stern, N. 2007. *The Economics of Climate Change. The Stern Review.* Cambridge University Press.
Watson, R.T., Zinyowera, M.C., and Moss, R.H. (eds) (1996) *Climate change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Contribution of working group III to the second assessment report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge.
Wikipedia Web site (2007). Global Warming. <en.wikipedia.org/wiki/Global_warming> and <en.wikipedia.org/wiki/Temperature_record_of_the_past_1000_years.
World Resources Institute 2006. Climate Analysis Indicators Tool (CAIT) on-line database version 3.0 Washington DC. Web site: <http://cait.wri.org>

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 25-27.

APPENDIX TO THE INTERNATIONAL PANEL ON CLIMATE CHANGE , THE STERN REVIEW, AND SCOTLAND.

CARBON FOOTPRINTS AND CARBON OFFSETTING.

Azra Meadows and Peter S Meadows
Division of Environmental and Evolutionary Biology,
Institute of Biomedical and Life Sciences,
University of Glasgow, G12 8QQ.
gbza31@udcf.gla.ac.uk

CARBON FOOTPRINTS (http://www.carbonfootprint.com)

Much can be done at a personal level, by reducing one's *carbon footprint.* This quantifies the impact of human activities on the environment in terms of the amount of greenhouse gases produced, and is measured in units of carbon dioxide. The following examples are starting points. All of them will reduce an individual's or household's carbon footprint. Use energy saving light bulbs, put thermostatic valves on radiators, turn central heating temperatures down, and switch off lights when not in a room. Fit double glazing, and insulate hot water tanks, lofts, and cavity walls. As one specific example, if everyone in the UK insulated their lofts and cavity walls it would cut CO_2 emissions by 11.9 million tons of carbon dioxide a year, with a financial saving of about £650 million. According to the Energy Savings Trust (EST), cavity wall insulation reduces heat loss by about 60% and it saves £120 annually on heating bills.

When travelling, consider sharing cars to work and for children's school runs. Walk, cycle, or use public transport for local shopping. For longer distances, consider traveling by train or bus rather than by car or plane. When on holiday, walk or hire a bike, and ask for your hotel room towels to be changed on alternate days rather than daily. If you are thinking of replacing your car, check the Biodiesel option.

Appendix Table 1 lists electrical appliances that are used daily in the home, with their power and cost of electricity used. The oven, television and computer are the three items with the highest electricity running costs.

Finally, try to minimise your carbon footprint at work, by switching off your eomputer when you are away from your desk, and turning off the office lights when you leave the office. Only print documents that are necessary, and print two pages to a side and double sided, and re-use the blank side of printed page.

Appendix Table 1. Daily electrical appliances and their power (wattage), usage, and cost in electricity (modified from website http://www.carbonfootprint.com/energy_consumption.html).

Appliance	Power (W)	Usage / day (hour)	Cost/day (pence)	Cost / year (GBP)
1x100W standard light bulb	100	4	4	14.60
1x18W Low Energy Light Bulb	18	4	0.7	2.68
Washing Machine	930	1.5	14	7.25 (1 wash per week)
Tumble Drier	2667	0.8	20	10.40 (1 wash per week)
Kettle	2200	0.2	3.7	13.40 (5 boils / day)
Electric Oven	1800	1	18	65.70
Microwave	1700	0.2	2.8	10.34
Television	290	4	11.6	42.34
Computer	250	2	5	18.25
Vacuum cleaner	630	0.5	3.2	3.28 (2 per week)
CD Player	85	1	0.9	3.10
Hair dryer	2000	0.1	1.3	4.87

Online calculation of personal Carbon Footprints

You can calculate your personal primary carbon footprint online. This is based on your household fuel bills and your annual travel. The website is http://www.carbonfootprint.com/calculator.html

As an example the authors have used their activities in the year 2006 to calculate their personal primary carbon footprint as follows.

- ***Household Fuel Usage***

Annual electricity usage = £300 (cost of annual bill)
Annual natural gas usage = £200 (cost of annual bill)
Annual LPG usage = nil
Annual coal usage = nil
Annual household oil usage = nil
Does your electricity come from renewables? No
How many people live in your house? 2

- ***Travel during past year (household or personal)***

Annual car no. 1 total mileage = 3,500
Annual car no. 2 total mileage (if you own a second car) = nil
Annual train journeys (miles travelled) = 4,000
Annual underground/local bus (miles travelled) = 300
Annual long-distance bus / coach journeys (miles travelled) = 200
Annual air-travel / flights:
Number of return flights which most closely match the distance you fly
short haul = 8
medium haul = 2
long haul = 3

Appendix table 2 shows the authors' household CO_2 (kg) emission and their personal share of CO_2 (kg) emission. These are compared with UK averages. The figures demonstrate that the authors primary carbon footprint for gas, electricity, car, and public transport are under the UK average, while their work related flights are above average. The latter dramatically increases the primary carbon footprint. The direct message to the authors is to re-evaluate their use of plane travel, and where ever possible use the train or coach, instead, especially for short and medium haul flights. It is unfortunately unavoidable to use alternative travel for their international development work.

Appendix Table 2. A worked example giving CO_2 (kg) emissions from household and travel activities

Human activities / usage	Our household CO_2 (kg)	UK average household CO_2 (kg)	Our personal share of CO_2 (kg)	UK average CO_2 per person (kg)
Gas, coal and oil	1,300	3,876	650	1,615
Electricity	1,110	3,127	555	1,303
Private Car	986	2,600	493	1,083
Public Transport	227	869	114	362
Flights (work related)	18,500	1,562	9,250	651
Total Primary Footprint	**22,123**	**12,034**	**11,062**	**5,013**

The secondary carbon footprint is an impact caused by individual buying habits – for example buying out of season fruit or vegetables that have been flown or shipped from abroad, this converts into a higher carbon footprint. Try to buy local products such as food and clothing, or those that have not been imported from distant countries.

CARBON OFFSETTING

Carbon offsetting is a method of compensating for the emissions produced with an equivalent of carbon dioxide saving. The process of carbon offsetting involves two steps. The first is a calculation of your personal carbon footprint. For individuals, you can do this on-line with a real-time calculator. There is a separate service for businesses and organisations, and a free carbon footprint appraisal quotation can be obtained on request. The second step involves buying 'carbon offset' credits from emission reduction projects. These projects will prevent, have already prevented, or removed an equivalent amount of carbon dioxide somewhere else in the world.

OFFSETTING BY PLANTING TREES

Carbon emissions can be offset by pledging a tree.
Each tree planted offsets one's personal environmental impact by absorbing approximately 730 kg CO_2 for photosynthesis during its lifetime. A recent web site (http://www.carbonfootprint.com/shop00.html) estimates that the average person needs to save about 7,000kg of CO_2 per year. So planting 10 trees per year is one strategy for achieving this. The trees also provide sustainable habitat for wildlife and will enhance the natural landscape with native broad-leaved trees. Pledging a tree via this web site costs £12. So the yearly cost is £120. The same

web site lists planting trees in the Great Rift Valley in Kenya – a developing country area, as costing £10 per tree, or £100 per year. This helps rural communities by providing fodder for livestock and also increased habitats for wildlife.

A related scheme is to offset your carbon emissions from a short haul flight (offsets 600kg CO_2 and costs £6.80), medium haul flight (offsets 1300kg CO_2 and costs £13.60), and long haul flight (offsets 3700kg CO_2 and costs £34.00). To register logon to http://www.carbonfootprint.com/shop0a.html.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 29-30.

SELF SEEDING AND EPIPHYTIC HABIT IN *GRISELINIA LITTORALIS*

Glyn M. Collis & Dawn Collis
Seasgair, Ascog, Isle of Bute, PA20 9ET.

ABSTRACT
The New Zealand shrub/tree *Griselinia littoralis* is regarded as persistent in the British flora, but infrequently reported as self-seeding. We report observations on the Isle of Bute and elsewhere of seedlings growing epiphytically, out of the reach of deer, and in fenced areas where deer are excluded. We suggest that deer may be a significant reason for the paucity of observations of self-seeding in this species and more important than rabbits in this respect. Our observations are discussed in relation to the effects of deer in its native New Zealand and the epiphytic habit in the genus *Griselinia*.

INTRODUCTION
Griselinia littoralis is a shrub or small tree, native to New Zealand. It is popularly grown in mild coastal areas of the UK as an attractive evergreen shrub with apple-green (or variegated) leaves, and also as a hedging plant valued for its resistance to salt winds. The flowers are small, green and inconspicuous. It is by far the best known of the 7 Species of *Griselinia*, two of which come from New Zealand, and the remainder from Chile and elsewhere in South America (Dillon & Munoz-Schick, 1993). The genus is placed in a family of its own, the Griseliniaceae. For a long time it was classified as a dogwood, Cornaceae, but molecular genetics has confirmed suspicions that it does not belong there; instead it seems to be an early offshoot from the evolutionary line that led to the modern Apiales - umbellifers and their allies (e.g. Chandler & Plunkett, 2004).
G.littoralis is dioecious (male and female flowers on different plants) and in cultivation it is usually propagated by cuttings. The species is a persistent element of the British flora. Stace (1997) records it as self-seeding "sometimes". Preston, Pearman and Dines (2002) report that it seldom fruits and "self-seeding is only very rarely reported". One possible explanation for this is that plants in a particular area may be of one clone, and thus all of the same sex, as suggested by Bean (1973). Here we suggest that depredation by deer is an important factor. Our evidence is a high prevalence of seedlings with an epiphytic habit in an area where ground-living seedlings are infrequent and short-lived, supported by observations of ground-growing seedlings in fenced areas.

OBSERVATIONS
On the Isle of Bute near Ascog, in open woodland that was once part of the grounds of Millbank House but untended for many years, there is a pair of unusually well grown fruit-bearing specimens of *G.littoralis*, about 18m and 8m in height respectively and about two metres apart. There is an additional specimen, also female and about 15m tall, about 75m away. In October 2003, about 15m from the pair of trees, we found a *G.littoralis* seedling in a fork in a 35cm diameter branch of a mature Common Lime tree *Tilia* x *europeae* that had fallen some years previously. There was considerable growth from the Lime which was clearly subsequent to its fall because it was vertical growth from the horizontal trunk. The scale of this growth and the size of the *G.littoralis* seedling indicated that the seed had germinated subsequent to the fall of the Lime, at a position about one metre above the ground. Its size and woodiness indicated that it had been there at least one winter, and it was thriving 12 months later when the fallen lime was cleared away
In September and October 2004, we found more seedlings of *G.littoralis* when some other large trees were felled on the same plot as a prelude to building work. Two seedlings were found together with an ivy seedling growing in a broken 24cm diameter branch near the crown of a Copper Beech *Fagus sylvatica pupurea* which was growing in close proximity to the fallen lime. When they germinated, the *G.littoralis* seedlings would have been at a height of 6 metres above ground level and a distance of 15 metres from the nearest mature *G.littoralis*. The two seedlings were less than 3cm apart and, since they were at the same stage in development, had most likely germinated in the same season. We also found *G.littoralis* seedlings nearby on a felled Sycamore *Acer pseudoplatanus* and an Ash *Fraxinus excelsior*. The heights of these seedlings too would have been at least 6 metres above ground level. All these seedlings had clearly survived at least one winter and summer and probably longer. However, it is likely that from time to time moisture levels at such microsites will fall to a level such that the seedlings are unlikely to survive for we have found no larger specimens growing high on trees.
We eventually found some small seedlings on the ground below the mature *G.littoralis* trees at the Bute site, but they did not persist, most likely because of grazing by deer. The two *G.littoralis* trees have a distinct browse line about 1m above the ground, indicating that the local Roe Deer *Capreolus capreolus* find it highly palatable, and Coles (1997) classifies *G.littoralis* as "very vulnerable" to deer damage. The browse lines are consistent with the view that Roe Deer are more significant than rabbits in limiting *G.littoralis* growth in this location and we have also seen a small specimen, surrounded by a rabbit-proof cylinder of wire netting, neatly cropped above the top of the netting about 60cm above ground. The seedling on the fallen Lime at a height of about 1m was probably made inaccessible for browsing by deer because of the acute angle of the fork in which it was found and the large size of the branches involved.
We have also found seedlings in the "Wee Garden", a fenced area within Mount Stuart Gardens on Bute. Some of these plants have grown to about 1.5m in height and are themselves flowering. In the grounds of Brodick

Castle on Arran, where deer are similarly excluded, there are places where the ground is carpeted with *G.littoralis* seedlings. Seedlings are also present in Logan Gardens on the Mull of Galloway even though rabbits can be observed feeding within the fenced area there, and Bean (1973) reports G.littoralis seedlings at Inverewe Gardens, Wester Ross. Thus, a good case can be made that deer prevent the establishment of seedlings at ground level. Where deer have access, there is preferential short-term survival of seedlings growing epiphytically beyond the reach of deer.

DISCUSSION

It is not uncommon for *G.littoralis* to grow epiphytically in the higher humidity temperate forests of its native New Zealand. For example Veblen and Stewart (1980) reported that, at four study sites, 90%, 78%, 54% and 22% respectively of *G.littoralis* saplings were established on logs or tree ferns. These high percentages are possibly a consequence of the removal of ground-growing individuals by the introduced White-tailed Deer *(Odocoileus virginianus)*. Interestingly, Veblen and Stewart noted that deer are not necessarily wholly detrimental to the progagation of *G.littoralis* since, without their browsing activity, forest floors lacked light and space making it harder for seedlings to get established, a factor perhaps unlikely to apply in the less dense woodland of Western Scotland.

Whereas an epiphytic habit is occasional in *G.littoralis*, in the closely related New Zealand species *G. lucida* it is the norm for young seedlings to grow epiphytically, subsequently sending roots down to the ground to establish themselves as separate trees (Cave & Paddison, 1999; Dillon & Munoz-Schick, 1993). In addition, *G. ruscifolia* is reported "often" to grow epiphytically on tree trunks in its native Chile (Dillon & Munoz-Schick, 1993), so there may be factors in the biology of the genus favourable to an epiphytic habit.

It is not likely that browsing or grazing is the sole reason why self-seeding is so seldom recorded for *G.littoralis* in the UK. We have already mentioned Bean's suggestion that all individuals in a particular area may be of the same sex, though this may be less significant nowadays with the ready availability of *G.littoralis* plants from a wide range of retail outlets supplied from different nurseries. To date, we have not located a male near to the Millbank site but, since the female flowers have produced viable seed, we know there is one near enough. Size and free growth may also be important factors for seed production. Since flowers are produced mainly on new growth, few are found on trimmed hedges. We have seen only a few plants less than 1m tall bearing flowers or fruit, while many of the fruiting specimens that we have seen on Bute and Arran are much larger than is common in garden specimens, and all were rarely pruned or trimmed.

REFERENCES

Bean, W.J. (1973). *Trees and Shrubs Hardy in the British Isles, 8th edition*. London: John Murray.

Cave, Y. & Paddison, V. (1999). *Gardener's Encyclopaedia of New Zealand Native Plants*. Aukland: Godwit/Random House.

Chandler, G.T. & Plunkett, G.M. (2004). Evolution in Apiales: nuclear and chloroplast markers together in (almost) perfect harmony. *Botanical Journal of the Linnean Society*, 144, 123-147.

Coles, C. (1997). *Gardens and Deer*. Shrewsbury: Swan Hill Press/Airlife Publishing.

Dillon, M.O. & Munoz-Schick, M. (1993). A revision of the dioecious genus *Griselinia* (Griseliniaceae) including a new species from the coastal Atacama Desert of northern Chile. *Brittonia*, 45, 261-274.

Preston, C.D., Pearman, D. A. & Dines, T. D. (2002). *New Atlas of the British and Irish Flora*. Oxford: Oxford University Press.

Stace, C. (1997). *New Flora of the British Isles*. Cambridge: Cambridge University Press.

Veblen, T.T. & Stewart, D.H. (1980). Comparison of forest structure and regeneration on Bench and Stewart Islands, New Zealand. *New Zealand Journal of Ecology*, 3, 50-68.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 31-37 .

TERRESTRIAL INVERTEBRATES, OTHER THAN INSECTS, RECORDED ON THE ISLE OF RUM, 2000

Compiled by Gordon B. Corbet
Little Dumbarnie, Upper Largo, Leven, Fife, KY8 6JG

ABSTRACT
Terrestrial invertebrates other than insects recorded on Rum in 2000 are listed. These comprise the following (total number of species, with the number apparently new to Rum in parentheses): Turbellaria (1), Mollusca 10 (4), Isopoda 6 (2), Araneae 86 (23), Pseudoscorpiones 1, Opiliones 8 (3), Acari 10 (8), Diplopoda (10), Chilopoda (10). One millipede, *Chordeuma proximum,* had not previously been recorded in Scotland.

INTRODUCTION
Between 27th August and 1st September 2000 a group of (mainly) entomologists met on Rum to record insects and other terrestrial invertebrates, following a similar survey done in 1990 (Hancock, 1992). The insects have been reported upon by Wormell (2006 – this issue of the Glasgow Naturalist). The other groups, dominated by the spiders, are reported here. All species that appear to be new to the island, or not previously published, are preceded by *.

Unless otherwise stated all records were made between 27 August and 1 September 2000. The exceptions are: (1) records from pitfall traps set by David Beaumont in May and July 2000, examined July and August 2000 respectively; (2) records from samples of leaf-litter collected at Kinloch in November and December 2000 by Kathy Sayer and Malcolm Whitmore, analysed and identified by GC.

Initials are used to indicate the identifier or collector as follows.

DB: David Beaumont (mainly spiders)
KB: Keith Bland (mite-galls)
GC: Gordon Corbet (arachnids, molluscs, myriapods)
MD: Mike Davidson (arachnids, myriapods)

The principal localities to which records refer are as follows; the 'tree plots' are those established anew since the 1950s:

Askival, NM 3995
Barkeval, summit, NM 376971 (591m)
Coire Dubh, c.400m, NM 3897
Guirdil, close to shore, NG 320014
Guirdil tree plot (pitfalls), NG 319008
Hallival, N face at 500m (pitfalls), NM 392967
Harris, close to shore, NM 3395
Harris tree plot (pitfalls), NM 338961
Kilmory Fank tree plot (pitfalls), NG 363008
Kilmory dunes and shore, c.NG 363039
Kinloch (pitfalls), NM 402992
Loch Scresort, S side, NM 4199
Loch Scresort, N side, NM 408998
Monadh Dubh, NG 3402

PLATYHELMINTHES: FLATWORMS
Turbellaria
* *Microplana terrestris* (Müller). Kinloch, Dec.00, 1 in leaf-litter at bridge over Kinloch R. (GC).

MOLLUSCA
Incidental records of terrestrial snails only; alive unless otherwise stated. All records by GC. *: species not shown for Rum in the atlas (Kerney, 1999.)

Cochlicopidae
* *Cochlicopa lubrica* (Müller) *s.s.* Kinloch: policy woods, tree nursery and reserve office; N shore L Scresort; Guirdil tree plot.

Pupillidae
Lauria cylindracea (da Costa). Kinloch, at foot of mortared wall; L Scresort, N shore, on coastal grass.

Discidae
Discus rotundatus (Müller). Kinloch, abundant in policy woods.

Zonitidae
Aegopinella nitidula (Drapernaud). Kinloch, frequent in policy woods; Guirdil tree plot, 4 in pitfall.
* *Nesovitrea hammonis* (Ström). L Scresort, N shore, 1 empty but fresh shell, short turf.
Oxychilus alliarius Miller. Kinloch policy woods.
Vitrea crystallina (Müller). Kinloch, at foot of mortared wall; L Scresort, N shore, 4 amongst coastal rocks.

Euconulidae

* *Euconulus fulvus* (Müller) *s.s.* Guirdil tree plot, 1 in pitfall; Kinloch, 1 foot of mortared wall; L Scresort, N shore, 1 in short grass.

Clausiliidae

Clausilia bidentata (Ström). Harris, 2 on cliff.

Helicidae

* *Candidula intersecta* Poiret. Kilmory, abundant on machair.

CRUSTACEA

Isopoda: woodlice

*: Species not shown in the atlas (Harding & Sutton, 1985).

Ligiidae

* *Ligia oceanica* (L.). L Scresort, several at HWM (GC, MD).

Trichoniscidae

* *Androniscus dentiger* Verhoeff. Kinloch, under stone near castle wall; 1 in leaf-litter at bridge over Kinloch R, Nov/Dec. (GC). Not recorded in the Inner Hebrides in the atlas.

Trichoniscus pusillus Brandt. Kinloch woods; Monadh Dubh, amongst *Molinia* etc.

Oniscidae

Oniscus asellus L. Widespread on coast and on hills: Kinloch, Harris, Askival, Monadh Dubh.

Philosciidae

Philoscia muscorum (Scopoli). L Scresort, N shore, in short dry turf just above HWM; Harris tree plot.

Porcellionidae

Porcellio scaber Latreille. Common on coast: Kinloch, Harris, Kilmory.

ARANEAE: SPIDERS

Usher (1968) produced a list incorporating records from his own survey in May 1966 along with earlier published and unpublished records. A survey in 1990 by D.Beaumont, J.Stewart and D.Horsfield resulted in 69 species of which 22 were new to the previous list (Stewart, 1992), increasing the total from 72 to 94 species. In 2000 86 species were recorded of which 23 were new. The national 10km atlas (Harvey *et al.,* 2002) enables records from Rum to be seen in a wider context.

Segestriidae

Segestria senoculata (L.). Harris, 1 f by burn; Kilmory Bay, 1 f under stone (both MD).

Oonopidae

* *Oonops pulcher* Templeton. Kinloch, 1f in grassland near burn and wood (MD). The atlas shows records from Canna and Skye for the period 1900-49.

Theridiidae

Enoplognatha ovata (Clerck). Harris, 1f in tree plot (MD).

Pholcomma gibbum (Westring). Monadh Dubh (150m), 1 subad.m swept from *Molinia* etc (GC).

* *Robertus arundineti* (O.P.-Cambridge). Under stones and prostrate juniper on Hallival (DB). Not included in previous published lists, but recorded in the atlas for Skye, Canna, Colonsay and Islay, and for NM49 which could be Rum or Eigg.

R.lividus (Blackwall). Askival, 1f near summit; Barkeval (c.570m), 1m; Hallival, 1f near summit (all MD); Guirdil, pitfalls; Harris, tree plot.

Linyphiidae

* *Agyneta ramosa* Jackson. Kilmory Fank, in pitfall, 2 vi – 27 viii 00; Harris, in tree plot (both DB). Recorded on Islay and Colonsay and very sparsely elsewhere in Scotland.

* *A.subtilis* (O.P.-Cambridge). Hallival, 4m, 1f in pitfalls; Kilmory Fank, 3m in pitfalls; Harris (DB, GC).

Bathyphantes gracilis (Blackwall). Kilmory tideline, 1m (GC); Kinloch and Guirdil, in pitfalls in tree plots (DB); in leaf-litter at Kinloch, Nov./Dec.00 (GC). Not listed by previous authors, but a record from NG30 (NW Rum) for 1950-1979 is shown in the atlas. Otherwise recorded in the Hebrides only on Islay.

Centromerita concinna (Thorell). Askival, 1m near summit; Barkeval (c.570m), 1m, 4f; Hallival, 2m, 4f near summit (all MD).

Centromerus prudens (O.P.-Cambridge). Askival, 1f near summit (MD); Hallival, under stones and prostrate juniper (DB).

Ceratinella brevipes (Westring). Harris, 1f amongst grass below raised beach (GC); Kilmory Fank (DB).

* *C.brevis* (Wider). Kinloch, 2f in deciduous woodland (MD). This species has been recorded on Canna.

* *Cnephalocotes obscurus* (Blackwall). Harris, 1f in tree plot (MD). There are records from Canna and Skye.

Dicymbium nigrum (Blackwall). Guirdil, 1f amongst coastal grass; Harris, 2m above shore (MD).

* *D.tibiale* (Blackwall). Barkeval (c.570m), 1f (MD); Guirdil tree plot, pitfalls; Kilmory Fank pitfalls, 1m, 2 vii-11 viii 00 (det.GC), 3 v- 31 viii 00 (DB). Not previously recorded in the Hebrides north of Colonsay.

Diplocentria bidentata (Emerton). Askival, 1f near summit; Barkeval (c.570m), 1m,1f (both MD).

Diplocephalus latifrons (O.P.-Cambridge). Harris tree plot (DB); Kinloch, pitfall in woodland 1 viii – 1 ix 00. Not included in previous lists, but shown in the atlas for NM49, presumably based on a record from Kinloch, 13 viii 94 (NBN Gateway). Otherwise recorded in the Hebrides only on Islay.
* *D. permixtus* (O.P.-Cambridge). Guirdil, pitfalls 3 v – 31 viii 00; Harris tree plot, 27 viii 00 (both DB). A widespread species, recorded on Islay, Skye and Barra (Outer Hebrides).
Erigone arctica (White). Kilmory, 2m, 3f on beach (MD); L Scresort, N shore, 3f in tideline wrack (GC).
E.promiscua (O.P.-Cambridge). Barkeval (c.570m), 2f; Harris, 1f by burnside; Kilmory, 1f on dunes, 1f on vegetated shingle by burn (all MD).
Gonatium rubens (Blackwall). Coire Dubh (c.400m), 1f; Kilmory, 1f on dunes; Kinloch Glen (NM 396999), f on whin and heather (GC, MD). No previous published record except that the atlas records it for NW Rum, 1950-79.
* *Halorates reprobus* (O.P.-Cambridge). L Scresort N shore, 2f under stones on saltmarsh (GC); 2m on shore (MD). A strictly coastal species hitherto recorded in the Hebrides only on Skye.
* *Hilaira excisa* (O.P.-Cambridge). Guirdil, in pitfalls 3 v – 31 viii 00 (DB). Hitherto recorded in the Hebrides only on Islay, but fairly widespread on the mainland in wet sites.
Lepthyphantes alacris (Blackwall). Kinloch, f in leaf-litter at bridge over Kinloch R, Nov./Dec.00 (GC).
L.ericaeus (Blackwall). Coire na Loigh (NG 331009), 280m, 1f in grass litter (GC); Harris, 1f above shore, 2f by burn (MD); Kilmory Fank, pitfalls (DB).
L.mengei Kulczynski. Dibidil track (NM 4098), 150m, 1f; Kinloch shore, 1f (GC).
L.minutus (Blackwall). Kinloch, 1m on outside wall of castle, 2f in grassland (MD).
L.tenebricola (Wider). Guirdil, pitfalls (BD); Harris tree plot (DB); Kilmory Fank, 3m,1f in pitfalls, 2 vii-11 viii (det.GC).
L.tenuis (Blackwall). Guirdil, pitfalls (DB); Harris, 2m above shore (GC); Kilmory, 2m, 1f on dunes (MD).
L.zimmermanni Bertkau. Coire Dubh, 1f (MD); Guirdil, pitfalls; Kinloch, pitfalls (DB); L Sgaorishal (NG 350022), 220m, f on *Calluna* (GC).
Linyphia triangularis (Clerck). Kinloch, 1m, 1f in grassland near burn and wood (MD).
Meioneta nigripes (Simon). Hallival, 2m in pitfalls (GC) and under prostrate juniper (DB).
Micrargus apertus (O.P.-Cambridge). Askival, 1f near summit; Barkeval (c.570m), 2m, 1f; Hallival, near summit, 1f (all MD).
Microlinyphia pusilla (Sundevall). Kinloch Glen (NM 396999), 3 immature on *Calluna/Juncus* (GC).
* *Minyriolus pusillus* (Wider). Kinloch, 1m in deciduous woodland (MD). Recorded in the Hebrides only on Skye and Colonsay.
Monocephalus fuscipes (Blackwall). Barkeval (c.570m), 2m,3f; Kinloch, 2m,3f in woodland (both MD); also in pitfalls at Guirdil, Harris and Kinloch (DB).
Neriene peltata (Wider). Kilmory, in pitfalls (DB).
* *Oedothorax fuscus* (Blackwall). Guirdil, m foot of cliff (GC); Harris, 3m, 1f (MD); Kinloch, 1f in grassland; L Scresort N shore, 2m, 1f in tideline wrack (GC); Kilmory Bay, 1m under stone (MD). Recorded widely elsewhere in the Hebrides.
Pocadicnemus pumila (Blackwall). Barkeval (c.570m), 1f; Kinloch, 1f in deciduous woodland (both MD).
Saaristoa abnormis (Blackwall). Between Askival and Hallival (NM 393959, 600m), 1f (GC); Coire Dubh (MD).
* *Savignia frontata* Blackwall. L Scresort, 1f on shore (MD). Recorded on Skye and the Outer Hebrides.
* *Silometopus ambiguus* (O.P.-Cambridge). L Scresort N shore, 1m,1f in tideline wrack (GC). A strictly coastal species, known from Mull, Colonsay and S Uist.
Tapinopa longidens (Wider). Coire Dubh; Hallival, 1f near summit (both MD).
Tiso vagans (Blackwall). Kilmory, 1f amongst grass (MD).
Walckenaeria acuminata Blackwall. Barkeval (c.570m), 1m (MD); Kilmory Fank tree plot, 2f in pitfalls, 2 vii-11 viii (det.GC); Harris, woodland (DB).
* *W.antica* (Wider). Askival, summit area, 1f; Harris, 1m above shore (both MD). Recorded widely elsewhere in the Hebrides.
W.cuspidata Blackwall. Kilmory tree plot, in pitfall (DB).
* *W.nudipalpis* (Westring). Hallival, summit area, 1m (MD). Recorded on Skye in the atlas; and Eigg, May 2001 (GC, unpublished).

Tetragnathidae

Metellina merianae (Scopoli). Coire Dubh (c.400m), Kilmory, 1f on dunes (MD); Monadh Dubh, 1f swept *Molinia* etc. (GC).
M.segmentata (Clerck). Widespread and abundant on trees and long grass/rush: Monadh Dubh, Kilmory Bay, Kilmory (dunes and Fank tree plot), Kinloch, Kinloch Glen, Harris.
Pachygnatha clercki Sundevall. Kinloch, 1m in wet area (MD).
P.degeeri Sundevall. Harris, 1f by burn, 1m,2f above shore, 1m,1f in tree plot; Kilmory, 1m amongst grass; Kinloch, 1m by pond (all MD).
Tetragnatha extensa (L.). Widespread and abundant on low vegetation (all immature); up to c.400m at Coire Dubh.

Araneidae

Araneus diadematus Clerck. Widespread on coastal cliffs, inland rocks up to 400m and on trees: Coire Dubh, Harris, Kilmory Bay, Monadh Dubh, Glen Shallisder; L Scresort (on pine).

A.quadratus Clerck. Kilmory Burn, 1f; Kinloch, 1f in grassland by castle (MD).

Larinoides cornutus (Clerck). Coire Dubh (c.400m), Kilmory Burn, 1f on vegetated shingle (MD).

* *Zygiella x-notata* (Clerck). Kinloch Castle, abundant indoors (GC, MD). Recorded sparsely in the Hebrides and West Highlands.

Lycosidae

Alopecosa pulverulenta (Clerck). Barkeval (c.570m), 1f (MD); Kilmory dunes, 1j; Monadh Dubh, *Molinia* etc., subad.m; Dibidil track (NM 4094, 350m) (all GC).

Arctosa leopardus (Sundevall). Kinloch, 1f by pond (MD).

Pardosa amentata (Clerck). Kinloch, f amongst rubble (GC).

P.nigriceps (Thorell). Kinloch, 2f in wetland (MD).

P.palustris (L.). Harris, in pitfall (DB).

P.pullata (Clerck). Kilmory Fank, in wet heath (DB).

P.uliginosus (Thorell). Kilmory Fank, in wet heath (DB).

* *Pirata hygrophilus* Thorell. In pitfall at Kilmory Fank tree plot, 2 vi – 27 viii 00 (DB). Recorded frequently in Skye and the West Highlands.

P.piraticus (Clerck). Kilmory Fank, in wet heath (DB).

Trochosa terricola Thorell. Harris and Kilmory, in pitfalls (DB); Monadh Dubh, rock in *Molinia/Calluna*, 1f; Harris, 3f edge of plinth of mausoleum (GC).

Agelenidae

Textrix denticulata (Olivier). Ruadh, Port na Caranean, (NM 427985), 2j on coastal rocks (GC); Kilmory Bay, Harris, amongst rocks (MD).

Hahniidae

Antistea elegans (Blackwall). Harris, 1f above shore (MD).

* *Hahnia helveola* Simon. Kinloch, 1m, 1f in deciduous woodland (MD). A scarce species in Scotland but recorded on Skye.

H.montana (Blackwall). Coire na Laoigh (NG 331009, 280m), 1f in grass litter (GC).

H.nava (Blackwall). N of Hallival (NM 3997) (DB).

Dictynidae

Cryphoeca silvicola (C.L.Koch). L.Sgaorishal, (NG 350022, 220m), f on *Calluna* (GC).

* *Dictyna arundinacea* (L.). Kinloch, 1f by pond (MD). An earlier record from Coire nan Grunnd, Rum (NM 405962) on 8 x 1994 is given in the NBN Gateway. In the Hebrides otherwise recorded only on Skye.

Amaurobiidae

Amaurobius similis (Blackwall). Kinloch Castle, 1m indoors (GC).

Clubionidae

* *Cheiracanthium erraticum* (Walckenaer). Kinloch, 1f by pond (MD). There appear to be no previous records of this species in the Hebrides nor the West Highlands other than a pre-1900 record in the Oban area, but it is fairly widespread in the eastern Highlands.

Clubiona diversa O.P.-Cambridge. Harris, 1m, 2f by burn; Kilmory, 1f on dunes (both MD).

* *C.neglecta* O.P.-Cambridge. Kilmory, 2f on dunes (MD). Recorded in the Hebrides only on Lewis and Colonsay.

C.reclusa O.P.-Cambridge. Kilmory tree plot, in pitfall (DB).

C.*trivialis* C.L.Koch. Kinloch, 1f by pond (MD).

Gnaphosidae

Drassodes cupreus (Blackwall). Head of Glen Shallisder (NG 340015, 50m), f under stone (GC).

Philodromidae

Tibellus maritimus (Menge). Harris, 1m on raised beach (MD). Not listed by previous authors but shown in the atlas for NW Rum.

Thomisidae

Ozyptila trux (Blackwall). Kilmory Fank, in wet heath (DB).

Xysticus cristatus (Clerck). Harris, 1f, Kilmory, 1f on dunes (MD); Kinloch Glen (NM 396999), subad.m on *Calluna/Juncus*) (GC).

* *X.erraticus* (Blackwall). Kilmory Fank tree plot, m on road (GC). Not hitherto recorded in the Hebrides north of Colonsay.

Salticidae

Neon reticulatus (Blackwall). Kinloch, 4f, 5imm. in deciduous woodland (MD); L. Sgaorishal (NG 350022, 220m), imm. in grass litter at edge of loch (GC).

PSEUDOSCORPIONES: FALSE SCORPIONS

Neobisium carcinoides (Herman). Allt nam Ba (NM 406943, 250m), 1 in leaf litter at foot of cliff (GC); Askival (NM 3895, 500m), 1 immature in clump of moss campion *Silene acaulis* (KB); Kinloch, deciduous woodland, 1 (MD). Recorded in previous lists as *N.muscorum.*

OPILIONES: HARVEST-SPIDERS

Previous records, of six species, were summarised by Usher (1968) and are included in the atlas (Sankey, 1988). Three further species were added in 2000.

Nemastomatidae

Nemastoma bimaculatum (Fabricius). Widespread in tree plots and on moorland to the highest summits (GC, MD).

Phalangiidae

* *Lacinius ephippiatus* (C.L.Koch). Guirdil, 1 at foot of cliff (GC); Kilmory Bay, 1m (MD); Kilmory Fank tree plot, 5 in pitfalls (det. GC). Recorded in the atlas from Skye and the southern Hebrides.

Mitopus morio (Fabricius). Widespread in tree plots and on moorland to the highest summits (GC, MD).

* *Oligolophus hanseni* (Kraepelin). Kinloch, in grassland near burn and wood (MD). The only site shown in the Hebrides or western Scotland in the atlas is in north Skye.

O.tridens (C.L.Koch). Kilmory, amongst grass; Harris, by burn and above shore (MD).

Paroligolophus agrestis (Meade). Widespread; Kinloch (on pine and amongst rubble), Harris, Kilmory (GC, MD).

Phalangium opilio L. Glen Shallisder (NG 340015, 50m), 1 amongst C*alluna* (GC); Kinloch, on castle walls, Kilmory Bay, Harris (MD).

Leiobunidae

* *Nelima gothica* Lohmander. Harris, grass below raised beach, 1 (GC), 1 by burn (MD); Kilmory Bay (MD); Kilmory, 1m, 3f on dunes, and by grassy stream valley (MD); Kinloch, on castle walls (MD). A scarce but widespread species in Scotland, mainly coastal, including records from N Skye, Barra and the vicinity of Mallaig.

ACARI: MITES AND TICKS

All records are by Keith Bland.

Eriophyidae: gall mites

Names follow those in *British plant galls* (Redfern & Shirley, 2002), which in turn was based upon the checklist of Amrine & Stasny (1994). All identifications were based upon the galls. Some earlier records were given by Harrison (1948).

* *Aceria macrorhynchus* (Nalepa). Kinloch, pimple galls on sycamore leaves.

* *A.thomasi* (Nalepa). Kilmory, Harris, galls on *Thymus.*

* *Eriophyes inangulis* (Nalepa). Kilmory, Kinloch, paired galls along midribs of alder leaves.

E.laevis (Nalepa). Kilmory, Kinloch, pimple galls on alder leaves.

* *E.pseudoplatani* Corti. Kinloch, erineum on underside of sycamore leaves.

* *E.sorbi* Canestrini. Kinloch, Kilmory, pustule galls on rowan leaves.

* *E.tiliae* Pagenstecher. Kinloch, erineum on underside of leaves of lime.

* *Phyllocoptes goniothorax* (Nalepa). Kinloch, curled leaf-edges of hawthorn.

* *P.populi* (Nalepa). Bagh na h-Uamha, near Standing Stone (NM 4197), erineum on underside of aspen leaves.

Ixodidae (ticks)

Ixodes ricinus (L.). Kilmory, several.

DIPLOPODA: MILLIPEDES

Millipedes have not been included in previous lists for the island, and none are shown in the provisional atlas (British Myriapod Group, 1988). Ten species were recorded in 2000, one being new to Scotland (*Chordeuma proximum*).

Craspedosomatidae

* *Nanogona polydesmoides* (Leach). Kinloch, in leaf litter in policy woods and under wood in tree nursery (GC).

Chordeumatidae

* *Chordeuma proximum* Ribaut. Kinloch: one adult male (plus 2 females and 3 immatures, probably the same species) in dead wood near the castle, 30 viii 00 (MD, det. GC); one adult male (plus several females and immatures) in leaf-litter at the bridge over Kinloch River, Dec.00 (GC). This is the first certain record of this species in Scotland; it occurs widely in SW Wales and sparsely across southern England, with one isolated record from Cumbria (NY 4973) on 20 xii 1987 (P.Lee, pers.comm.). Immatures of *Chordeuma* sp. found at Benderloch, Argyll in June 2001 (GC), Dunvegan, Skye in August 2003 (Barber, 2004) and Crianlarich, Perthshire in June 2004 (GC) are most likely to be this species. The record of an adult male on 30 August is of interest: Blower (1985) gives the end of September for the appearance of adults.

A preliminary note of this record appeared in the newsletter of the British Myriapod and Isopod Group (no.2) in spring 2001.

Blaniulidae

* *Archiboreoiulus pallidus* (Brade-Birks). Kinloch, in grassland near castle (MD, confirmed GC). The only other record from the highlands or islands of Scotland appears to be from Loch Carron (W Ross) in 2003 (Barber, 2004), but it is widespread in the lowlands of eastern Scotland.

* *Proteroiulus fuscus* (Am Stein). L Scresort, S shore, under dead bark (of larch?)(GC).

Julidae

* *Cylindroiulus latestriatus* (Curtis). Frequent in coastal grass: Kilmory, Harris, Kinloch (GC, MD).

* *C.punctatus* (Leach). Kilmory Fank tree plot, 1 in cattle dung just outside fence; L Scresort, S shore, under dead bark; Kinloch, woodland, grassland and tree nursery (GC, MD).

* *Ommatoiulus sabulosus* (L.). On ground in tree plots (abundant in pitfalls): Kilmory Fank, Harris, Kinloch (GC, MD).

* *Ophyiulus pilosus* (Newport). Kinloch: 12m in pitfalls.

* *Tachypodoiulus niger* (Leach). Harris tree plot, several; Kinloch, 4 in pitfalls; Kilmory Fank tree plot, 2 in pitfalls (GC, MD).

Polydesmidae

* *Polydesmus inconstans* Latzel. Kinloch: ad.m in leaf-litter at bridge over Kinloch R., Nov./Dec.00 (GC).

CHILOPODA: CENTIPEDES

There appear to be no previous records of centipedes on Rum and none are shown in the provisional atlas (Barber & Keay, 1988).

Himantariidae

* *Haplophilus subterraneus* (Shaw). Kinloch tree nursery (GC) and grassland (MD). Known from c.10 sites in Scotland, mostly from gardens in the south.

Schendylidae

* *Schendyla nemorensis* (C.L.Koch). Kilmory machair, 1; N of Hallival, 1 in pitfall (both GC); Coire Dubh (NM 3897) (MD, det. GC).

Geophilidae

* *Brachygeophilus truncorum* (Bergsoë & Meinert). Kilmory machair, 1; Kinloch: tree nursery, 1 (GC).

* *Geophilus easoni* Arthur *et al.* Guirdil, juv. under stone on old field; Coire Dubh, 1 under stone at c.400m (coll. MD). Both det. GC. This is a fairly widespread and common species although only recently recognised as distinct from the much more localised *G.carpophagus* (Arthur *et al.*, 2001).

G.insculptus Attems. L Scresort, S shore, 1f under sycamore (GC); Kinloch Castle, in grassland (MD).

Lithobiidae

* *Lamyctes fulvicornis* Meinert. Kilmory burn and dunes; head of Allt nam Ba (NM 3994, 450m); W slope Hallival (NM 390962, 500m); Harris cliff; summit of Barkeval, 1 eating a beetle, *Clivina fossor* (coll.R Key) (GC, MD).

* *Lithobius borealis* Meinert. Kilmory and Harris (MD).

* *L.forficatus* (L.). Widespread from the tideline to c.700m, below the summit of Hallival (GC, MD).

* *L.melanops* Newport. Kilmory burn and tideline; Harris, cliff and under dead wood in tree plot; Kinloch policy woods (GC, MD).

* *L.variegatus* Leach. Kinloch, woodland and tree nursery (GC, MD).

ACKNOWLEDGEMENTS

I am grateful to my fellow contributors, David Beaumont, Mike Davidson and Keith Bland, for their cooperation; to Kathy Sayer and Malcolm Whitmore for collecting winter samples of leaf-litter; and to Peter Wormell for organising the survey and checking a draft of this paper. Scottish Natural Heritage provided accomodation on Rum.

REFERENCES

Amrine, J.W. & Stasny, T.A. 1994. *Catalog of the Eriophyoidea of the World.* Indira Publishing House, Michigan.

Arthur, W. *et al.* 2001. Analysis of segment number and enzyme variation in a centipede reveals a cryptic species, *Geophilus easoni* sp.n. *Biological Journal of the Linnean Society* 74, 489-499.

Barber, A.D. 2004. Myriapods from Wester Ross and Skye. *Bulletin, British Myriapod and Isopod Group* 20, 25-33.

Barber, A.D. & Keay, A.N. 1988. *Provisional atlas of the centipedes of the British Isles.* Biological Records Centre, Huntingdon.

Blower, J.G. 1985. Millipedes. *Synopses of the British Fauna* (NS) 35, Linnean Society of London, London etc.

British Myriapod Group 1988. *Preliminary atlas of the millipedes of the British Isles.* Biological Records Centre, Huntingdon.

Hancock, E.G. 1992. Some records of terrestrial invertebrates from Rum National Nature Reserve 1990. *Glasgow Naturalist* 22 (2), 169–189.

Harding, P.T. & Sutton, S.L. 1985. *Woodlice in Britain and Ireland: distribution and habitat.* Biological Records Centre, Huntingdon.

Harrison, J.W.H. 1948. Zoocecidia in the Scottish Western Isles. *Entomologist's Monthly Magazine* 84, 113-116.

Harvey, P.R., Nellist, D.R. & Telfer, M.G. (editors) 2002. *Provisional atlas of British spiders (Arachnida, Araneae).* Biological Records Centre, Huntingdon.

Kerney, M. 1999. *Atlas of the land and freshwater molluscs of Britain and Ireland.* Harley Books, Colchester.

Redfern, M. & Shirley, P. 2002. British plant galls. *Field Studies* 10, 207-531.

Sankey, J.H.P. 1988. *Provisional atlas of the harvest-spiders (Arachnida: Opiliones) of the British Isles.* Biological Records Centre, Huntingdon.

Stewart, J.A. 1992. Araneae, pp. 183-5 in Hancock, E.G. (as above).

Usher, M.B. 1968. Some spiders and harvestmen from Rhum, Scotland. *Bulletin, The British Spider Study Group* no.39, 1-6.

Wormell, P. 2006. Scottish entomologists' survey: Isle of Rum, 2000. *Glasgow Naturalist.* Current issue.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 39-47 .

ARTIFICIAL REEFS: A REVIEW & CRITICAL PERSPECTIVE

William R. Hunter
Division of Environmental & Evolutionary Biology, University of Glasgow, Glasgow G12 8QQ

ABSTRACT
This paper provides a summary of the history and development of artificial reefs from their beginnings as a tool of the artisanal fisherman to their uses in fisheries management and environmental mitigation of pollution events. Artificial reefs have been deployed in 22 countries worldwide (Seaman, 2002) and have been used for a wide range of roles, yet the scientific literature regarding artificial reef research is still fraught with problems and controversy. In an effort to provide a strong base for future research this paper reviews a small cross-section of the ecological studies carried out on artificial reefs. The review found that lack of experimental replication was a consistent problem, with small sample sizes resulting in low statistical power. Additionally pseudoreplication of data was deemed to be an issue because of the lack of independence between sample sites. The studies reviewed tend to be limited by the economics and legal limitations of artificial reef deployment, and so in all but two of the studies artificial reefs deployed for another purpose were used in the experiment. In the future, replication is the key to obtaining meaningful quantitative data in artificial reef research. As with any field-based experiment certain assumptions and generalisations must be made in order to maintain an economical and achievable experimental design. However, this should be recognised and careful consideration of how it will affect the results should be undertaken by the researcher(s).

INTRODUCTION
Artificial reefs, as defined by Seaman and Jenson (2000), are effectively objects of natural or man-made origin, deliberately placed on the sea floor in order to influence some aspect of the marine resources in that area. These can consist of anything, from derelict vehicles, tyres or concrete blocks, to quarried rock or timber, and can be seen to have a wide variety of possible uses and impacts, which must be carefully considered before the deployment of the reef.

The aim of this short paper is to provide a review of the scientific literature published on artificial reefs and in particular the associated ecological impacts. The paper will provide a summary of the current level of scientific knowledge on artificial reefs and their uses worldwide. It will then assess and critically review a sample of the small number of studies within the literature which investigate the impacts of artificial reefs upon mobile macro-fauna with regard to experimental design. In particular this review will examine the problems associated with achieving adequate replication of samples, pre-deployment research, quantification of results and cost effectiveness in artificial reef research.

From this base artificial reefs can be examined within the context of whether or not they "make a difference" both ecologically and economically. In addition, the review will critically assess previous artificial reef research and examine the experimental criteria that should be considered in future studies.

SUMMARY OF HISTORICAL AND PRESENT APPLICATIONS
Historically artificial reefs have been documented in various forms as a tool of the artisanal fisherman who, observing that fish tend to aggregate in areas where the sea floor is heterogeneous in some way (e.g. rocky), learned to mimic this natural heterogeneity by dumping materials onto the sea floor (d'Cruz *et al.*, 1994). This is demonstrated by the fishermen of Japan (Meier er al., 1989) and the West African nations of Benin and Côte d'Ivoire. The fishermen in West Africa practise a traditional method known as Acadja, which involves placing a dense mass of woody branches into shallow water (~1m depth) of a lagoon. The acadja provides a heterogeneous environment, which not only attracts and aggregates fish, but also provides an ideal site for reproduction and growth of many fish (Hem and Avit, 1994). Although artificial reefs have a long history they were first used in the Far East (Kim, 2001) and the developing world their first deployment in the western world was in the 1950s, where reefs were deployed by the US Navy to enhance recreational fishing in California (Dreysher *et al.*, 2002).

In Europe the use of artificial reefs commenced in the 1960s in Monaco for conservation purposes. The reefs were deployed in 1979 in the marine reserve of Monaco (established in 1976). Designed to halt the progressive destruction of seagrass meadows, these reefs were deployed close to the shore and were observed to have developed a typical Mediterranean rocky reef fauna (Jenson 2002). A second reserve area was then designated in 1986, and artificial reefs were deployed with a view to cultivation of *Corallium rubrum* (Linnaeus), the red coral, with the coral being transplanted from a natural population and attached to cave walls in the reef with epoxy resin (Jenson 2002).

From this beginning interest in artificial reefs in Europe has increased, with the deployment of Large Artificial Reef Units in France since 1985 (Charbonnel *et al.*, 2002), the construction of the Loano artificial reef in the Liguarian Sea, Italy in 1986 (Relini *et al.*, 2002) and the construction of the Poole Bay artificial reef in the United Kingdom in 1989 (Jenson 2002). A total of nine European Union nations have licensed artificial reefs in their territorial waters, including the United Kingdom, France, Spain, Poland and the Netherlands, and several countries both within the EU and outside it have expressed interest in Artificial Reefs, including Ireland, Denmark, and Norway.

This interest in artificial reef technology has provided a wide scope for scientific investigation in Europe, and with the foundation of the European Artificial Reef Research Network in 1991, through funding by the European Commission (Jenson, 2002) a clear development of artificial reef science within Europe is underway, based on the pioneering studies of the last 30 years.

Outside of Europe 22 countries have artificial reefs deployed in their territorial waters, including the United States, Canada, India, and probably the world leader in artificial reef technology Japan (Grove *et al.*, 1994). This is based on the reports of the international Conferences on Artificial Reefs and Related Aquatic Habitats (CARAH) in 1991 and 1999 (Seaman, 2002), so the number may have increased or declined since then.

Worldwide artificial reefs serve many purposes, from fisheries enhancement and protection to environmental mitigation of pollution to tourism and as such provide a wide range of opportunities for the scientific study of their impacts *in situ*. However in order to be adequately studied any artificial reef must have a series of clearly defined goals, with which assessment can be made.

Fisheries Protection and Enhancement

As a fisheries protection tool the artificial reef has proved to be fairly popular across the globe. In Hong Kong, for example, artificial reefs are being deployed within designated marine-protected areas (MPAs) in an attempt to combat the depletion of fish stocks. The primary goals of the Hong Kong projects are to increase the depleted biomass and to re-establish populations of high-value commercial species in an effort to mitigate against the effects of over-fishing (Pitcher *et al.*, 2002).

Investigation of the use of decommissioned oil-rigs as artificial reefs has also been carried out with a particular emphasis on the impact on exploitable fish-stocks. This is exemplified by the North Sea Ekofisk oil field, which was assessed as a potential offshore reef site at the beginning of this century (Cripps and Aabel, 2002). In their Environmental Impact Assessment it was concluded that the use of the reef for protection of fish stocks could be of benefit, by providing refuge and food to juvenile fish, allowing increased recruitment to the exploitable populations from the reef. However, in contrast, a review by Sayer and Baine (2002) provides evidence that in the North Sea the rigs to reefs strategy would have little positive impact on fisheries and as such could be both an economic and ecological "white elephant."

The review by Sayer and Baine (2002) examined the potential for a North Sea rigs to reefs programme in comparison with the current programme being carried out in the Gulf of Mexico. It concluded that the environmental conditions in the North Sea differ greatly from the Gulf of Mexico where warm, shallow water combines with the high levels of inshore components to the oil production infrastructure, providing a rigs to reefs programme which mainly services the recreational fishing and diving markets. Additionally it was concluded that the loss of fishing exclusion, provided by the operational rigs in the North Sea, would adversely impact upon the commercial fisheries and thus negate the small increase in habitat which would become available through the deployment of decommissioned oil and gas rigs as artificial reefs.

Artificial reefs contribute to the enhancement of fisheries in two ways according to Seaman and Jenson (2000), firstly by attraction of mobile organisms to the reef, and secondly through habitat enhancement, which will in turn cause an increase in biomass at the site. However, this view of the reefs as additional habitat does not come without controversy over whether the reef actually does increase the productivity of an area, or whether it will merely act as an attractant, leaving other areas depauperate; the so called attraction- production controversy (Osenberg *et al.*, 2002). It is likely this is merely an effect of scale as increased fish populations are observed around artificial reefs (d'Cruz *et al.*, 1994; Lin and Su, 1994) and there is significant evidence that the fish populations of artificial reefs do contribute to the larval pool of reef fish in the surrounding area (Stephens and Pondella 2002).

Environmental Mitigation and Remediation

The use of artificial reefs as a form of mitigation measure against pollution has become increasingly important, and has thus provided the backdrop for much of the research carried out on artificial reef ecology. This particular use of artificial reefs has been applied mainly in the state of California, USA, where warm water outputs from Nuclear Power Stations proved detrimental to the growth of the giant kelp, *Macrocystis pyrifera* (Linnaeus), and thus to the associated ecosystems on the Californian coast. The use of artificial reefs, as a form of on-site mitigation resulted from the high costs associated with the alternatives, including re-routing of the discharge pipes, and the installation of salt water cooling towers. Examples of this include the Pendleton Artificial Reef (Grant *et al.*, 1982) and the 9 hectare experimental reef placed in the vicinity of San Onofre Nuclear Generating Station, Southern California. The San Onofre reef consists of 56 separate modules and provides a preliminary study, on which a further 61ha reef will be designed and deployed (Deysher *et al.*, 2002).

Artificial reefs have been deployed in the Republic of Maldives as a means of mitigating against damage done to natural reefs by coral mining, in particular around Malé Island. A study by Clark and Edwards (1994), describes the process of deployment of artificial reef structures to an experimental site on a reef flat in the Maldives. The findings of that study show a clear enhancement of the reef-flat ecosystem, with increased fish populations around the reef site, and successful recruitment and transplantation of coral species onto the reef modules. Their study, therefore, demonstrated the ability of artificial reefs in mitigating damage to important ecosystems, particularly in places like the Maldives, which rely heavily on their coral reefs for tourism, fisheries and coastal defence.

Another use of artificial reefs as a mitigation measure that has been investigated in the form of biofilters deployed in conjunction with fish farms. As the organic and nitrate output of fish cages is high, and much of this detritus sinks to the sea floor directly below the fish cage, a reef may provide a mitigation measure, by providing a substrate for biofouling and a heterogeneous environment which will attract many species capable of utilising the detrital rain in some way. This has been investigated in Israel (Angel and Spanier, 2002), and although the reef provided no change in the organic content of the water during the study period, it did increase the abundance of numerous species beneath the fish cage, mitigating the decline in biodiversity associated with fish cages.

On the whole the use of artificial reefs as bioremediation and mitigation tools is both a difficult and expensive solution. Large amounts of research need to be carried out, pre-deployment, followed by a limited experimental deployment, prior to full deployment. This is required to develop a reef which exhibits similarity to the receiving environment or surrounding reefs (Ambrose, 1994). Also these problems can be compounded by the complexity of the receiving ecosystem and direct restoration is not always possible (Pratt, 1994). As such, the rules of island biogeography are often simply applied, with the largest reefs possible being used, in order to provide a high level of habitat complexity.

Recreational Uses

The use of artificial reefs for recreational purposes has been popular, and has provided a strong socio-economic goal in their design Artificial Reefs have been used to enhance recreational fisheries; to provide attractions to SCUBA divers, e.g. the wreck of the Scylla, UK; and to influence the physical environment, improving wave formation for surfers.

Some of the first reefs to be deployed for recreational purposes were at Paradise Cove and Redondo Beach (both in California). These reefs, consisting of old car bodies and trams, respectively were sunk by the U.S. Navy in 1958 to support sport fisheries (Deysher *et* al., 2002). However the majority of reefs tend to have numerous goals, aside from attracting recreational users, but it is worth noting that this use is important, needing careful consideration in reef planning and licensing, as it can provide an important “market” for an artificial reef.

The recreational use of reefs often goes hand in hand with their use in environmental mitigation and conservation. One way that this objective is met is through the relief of natural reef sites, from the stress and disturbance factors associated with recreational use by humans (Abelson and Shlesinger., 2002).

Scientific uses of Artificial Reefs

The development of Artificial Reef programmes worldwide has fuelled scientific research into their uses, and impacts upon the environment. Thus effectively the scientific uses of artificial reefs goes hand in hand with meeting objectives of higher economic value, e.g. fisheries protection. However, there have been artificial reefs built worldwide with the primary goal of providing an experimental structure. Examples of these scientific reefs include the Poole Bay artificial reef and the Loch Linnhe artificial reef, both in the United Kingdom.

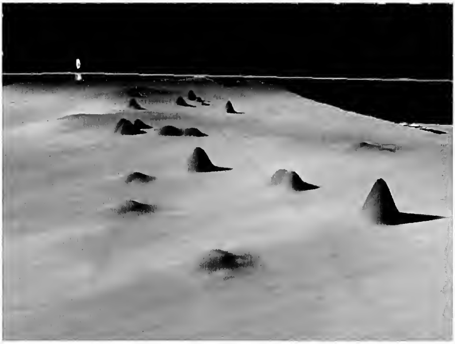
The Poole Bay artificial reef, deployed in 1989, was designed as an experiment on the impact of stabilized Pulverised Fuel Ash (PFA) blocks upon the environment. These blocks were composed of PFA waste from coal fired power stations and bound in a cement and aggregate mixture. Continuous monitoring was then undertaken to establish if any leaching of heavy metals from the blocks was occurring, and to observe the biotic colonisation of the reef (Collins and Jensen, 1997).

In July 1998 scrap tyre reef modules were deployed at the Poole Bay reef, alongside the PFA reefs, with the tyres being formed into definite structures, and filled with concrete. These modules were then deployed and monitored at bi-monthly intervals by SCUBA divers, who again studied the biological colonisation of the area and also the fate of the heavy metals bound within the scrap tyres. The results were presented in the form of an Environmental Impact Assessment (Collins *et al.*, 2002) and show a rapid colonisation of the reef modules by biofouling organisms, with a successional change from the initial algal colonists towards a hydroid dominated community. The new community included some bryozoans, ascidians, barnacles and worms and, as a result, an increase in mobile grazing species. Heavy metal leaching was demonstrated to have significant effects on biofouling organisms, in particular on the tyre reefs.

The Loch Linnhe artificial reef was licensed in 2001, for a proposed 24-module reef complex, of some 42,000 tonnes at a site on the east side of the island of Lismore (Sayer and Wilding., 2002) (Fig. 1), with deployment commencing in April 2003. Later the reef complex was redesigned to consist of 42 reef modules, at a weight of around 25,000 tonnes. Prior to the deployment of the Loch Linnhe artificial reef research was carried out at the proposed site and involved a sonar survey of the seabed, analysis of current speeds at the site, granulometric analysis, analysis of sediment redox potentials and sampling of the fauna associated with the site (Wilding and Sayer, 2002a). In addition, a detailed study of potential construction materials was undertaken, in order to select a construction material which would be environmentally safe and physically robust, at low production cost (Wilding and Sayer, 2002b).

Fig 1 Map showing the location of the Loch Linnhe Artificial Reef, within the wider Lynn of Lorne area

Fig 2 Multi-beam sonar image of the Loch Linnhe Artificial Reef, showing the two groups of six modules and the larger multi-drop reef module.



In its present form the Loch Linnhe artificial reef consists of five groups. Each group consists of six reef modules, three of which are constructed from complex blocks, and three constructed from simple blocks. Reef module size is relatively standard, at around 4200 blocks, and in total the design provides a high level of replication within the reef site. Additionally one multi-drop, consisting of three deployments of complex reef blocks has been made (Fig 2).

The Loch Linnhe artificial reef provides huge potential as a research tool. However at present its use is at a very early stage. It has been observed to provide new hard substrata with a significantly higher level of geometric complexity than the natural reefs in the surrounding area (Rose 2005). This increased habitat complexity has the potential to support higher levels of animal abundance than comparable natural reefs, and this has been observed in the wrasse species *Ctenolabrus exoletus*, Linnaeus, and *Crenilabrus melops*, Linnaeus, and in the crab *Necora puber* (Linnaeus) (Hunter, unpublished data). However the reef has also been observed to collect phytodetritus around the reefs edges and a decreased level of sediment oxygenation in area around each reef module (Wilding, 2006).

REVIEW OF LITERATURE

In order to adequately review a cross section of the literature related to artificial reefs, five papers were selected from peer-reviewed literature to be examined. These provide a typical sample of some of the research which has been carried out on artificial reefs. In particular these papers all deal with the effects of artificial reefs on fish and mega-invertebrate assemblages, either through comparison of artificial reef complexity (Charbonnel *et al.*, 2002), comparison of artificial reefs with natural reef and control sites (Fabi & Fiorentini, 1994; Fujita *et al.*, 1996) or simply by examination of the colonisation or aggregation of fauna upon the artificial reefs (Bortone *et al.*, 1994; Jensen *et al.*, 1994).

Comparison of Artificial Reef Complexity

The first paper considered was a comparison between two Large Artificial Reef Units (LARUs), of different complexity which were deployed in a Marine Protected Area on the French Riviera, at 27m depth (Charbonnel *et al.*, 2002). Deployment occurred between 1986 and 1987 with each LARU consisting of nine large concrete slabs, with void spaces occupying $158m^3$. In the experimental (complex) unit these void spaces were filled with $37m^3$ of building materials, piled up randomly by divers, in 1991, whereas the control (simple) unit was left untouched.

Data collection was by visual census, carried out by SCUBA divers, and each module was censused 17 times between February 1987 and July 1989, and then 20 censuses, after the manipulation of the experimental LARU, between October 1997 and July 1998.

The most striking issue within this study is the lack of replication. Only one experimental site and one control site were used, with data being collected both before, and several years after the manipulation of the control site by divers. This relies on the two sites being completely identical prior to the manipulative treatment, (Hurlbert, 1984), and unfortunately the study in question suffers two major problems because of this. Firstly there are relatively few samples taken from each unit prior to the manipulation by divers (only 17 over a one and a half year period) and secondly six years passed between the manipulation of the experimental unit and the second sampling period. This lack of sampling effort over time leaves the study in a weak position, because it is simply a comparison of two isolated sites, and so it is questionable whether or not the study can be used to draw any conclusions on the effect of reef complexity on faunal assemblages outside of the study site.

Pre-deployment research in this study is not a major issue because it is a test of the manipulation of the experimental site, and data were recorded prior to this occurring. However, as already stated the issue largely comes down to whether the number of samples taken before manipulation is sufficient to prove the two sites to be identical. Additionally the authors have supported their findings by examining work carried out by other authors, as well as carrying out work themselves, on fish assemblages on a Mediterranean artificial reef, and rock substratum, helping to support the study.

Quantification was also somewhat problematic within this study, as the main form of data collection was by SCUBA divers carrying out an unspecified visual census. No information on census strategy was given, which makes reliability difficult to assess. Alongside this the information on biomass was estimated from the relative abundance observed, which provides a very crude estimate, onto which statistical tests were applied.

Many of the issues of experimental design seem to originate from the unreplicated treatment. This may well be an economic issue, with regard to the cost of LARUs, and their primary goal being the conservation of *Posidonia oceanica* beds, leaving scientific study as a secondary goal, but it is clear that more care should have been taken in the data collection and analysis to overcome these issues. As a result the study is fundamentally flawed and adds little to the literature.

Comparison of Artificial reefs, Natural reefs and Control Sites

In comparing artificial reefs with other sites, including natural reef and control (sandy bottom) sites, two papers were examined. The first of these was a comparative study carried out on the Okama artificial reef, comparing it with a natural reef and a sandy-mud bottom site off northern Japan (Fujita *et al.*, 1996). The study was carried out using a bottom trammel net, on the three sites, each at a depth of 130m, over a six year period from May 1987 to March 1993. Between May 1987 and September 1990 24 samples were collected every two months at each of the three sites. Then from May 1991 to September 1991 ten additional samples were collected at the artificial reef site, and this was continued every two months from January 1992 to March 1993. As a result of this a large number of samples were taken using standardised equipment. The study, however, is of a non-replicated design examining three discrete sites, one artificial reef, one natural reef and one control site. Therefore, the results showing a greater level of fish abundance and species composition at the artificial reef, can only be used to draw conclusions about the isolated study sites. In order to allow meaningful conclusions to be drawn about differences in fish abundance and species composition to be drawn between artificial and natural reefs, a number of replicate sites of each treatment (artificial reef, natural reef and control) need to be investigated (Hurlbert, 1984).

In terms of pre-deployment research a fairly wide expanse of work has been carried out on the assemblages of demersal fish on the Northern Japanese continental shelf, using mainly trawling techniques on flat bottoms as a sampling method. However, it was only since the deployment of the reef, that "demersal fishes have been periodically sampled" (Fujita *et al.*, 1996). Therefore, greater rigour in the pre-deployment sampling was required in order to fully develop an understanding of the impact of the Okama artificial reef on community composition, and also provide some degree of historical control.

The study by Fujita *et al.* (1996) provided a good example of a quantitative study, providing information on the species composition between the three sites using catch rates, both in terms of number of species caught and number of individuals caught, comparing both site and annual overall catch rates. However, there was a tendency towards sampling bias by the trammel net, in that cryptic species tended to be under represented in the sample. This was recognised by the investigators, who stated that "catch efficiency for each fish should be taken into account in future works to obtain precise and quantitative data of the artificial reef fish community" (Fujita *et al.*, 1996), although it could be asked why this was not undertaken in the published study?

The paper by Fabi and Fiorentini (1994) provides a further study comparing an artificial reef site with a control site, over a four year period from 1988 to 1991. The artificial reef was constructed of 29 pyramidal structures, built from cubic concrete blocks. These were deployed in October 1987, along with four concrete cylinders and 12 concrete cages. The control site was an area of mud bottom, of similar depth to the reef site (10-11m), located 2.5 miles from the artificial reef, to maintain independence. Two survey methods were used, the first being a quantitative study using trammel net sampling and the second a more qualitative visual census by SCUBA divers.

Again in this study the investigation suffers from the lack of replication. If several independent artificial reefs had been established, and compared with a similar number of control sites, the data obtained would definitely be considered more reliable. However, because the experiment describes only two sites, with no real pre-deployment research, the impact of the reef deployment on species richness and abundance is largely speculative. Yet again it must be asked if the correlation between the conclusion and the results actually demonstrates a causative link, but as the objective of the investigation was the comparison of the sampling gear this did not prove a major problem.

The comparison of a quantitative trammel net survey with the more qualitative diver survey provided an interesting assessment of techniques, showing that both tended towards a bias, with the divers often missing sandy bottom, benthic fish species, and the net often under-representing cryptic reef dwelling fish (e.g. *Conger conger*). However, a well designed diver survey, involving either a transect counting technique or some form of timed count, for example the Visual Fast Count method (Kimmel, 1985), would have allowed a more quantitative diver survey to be undertaken, and thus perhaps provide a more meaningful comparison with the trammel net.

In both these studies it is clear that the economic expense of artificial reef use in the research is one of the major factors affecting the work. In both cases lack of replication of artificial reef structures was the limiting factor on the experimental design. This is likely to be because, as in Charbonnel *et al.* (2002), the reefs used were deployed to fulfil a particular goal other than scientific study. Therefore, the researcher is forced to compromise from the outset in order to maintain a cost-effective study and so must design their studies according to the limiting factor which is the number of artificial reefs available to them.

Colonisation and faunal aggregations on artificial reefs

Studies of the colonisation of artificial reefs, and examination of the faunal assemblages, in particular reef fish, have proved important in progressing the scientific understanding of marine ecology. Two studies were examined. One study examined the fish assemblages which developed on an artificial reef, in an estuarine environment in the Gulf of Mexico (Bortone *et al.*, 1994), and the other study examined the colonisation of an artificial reef complex deployed in Poole Bay, United Kingdom (Jensen *et al.*, 1994).

The work carried out in the Gulf of Mexico by Bortone *et al.* (1994) involved deploying twelve conical plastic reef modules, in four groups of three, into the Choctawhatchee Bay estuary, at a depth of 6.5m. These were surveyed by SCUBA divers using a point-count visual census method, over a 13 month period, commencing in October 1987 and continuing until October 1988. Each reef complex was surveyed once per month, over the 13 months, including 1 pre-deployment survey, so that a total of 52 surveys were undertaken over the study period.

This study examined the number of species, species abundance, fish length, biomass and species diversity. Additionally sediment samples were collected, in order to calculate mean grain size and weight, and this and other independent variables recorded. The statistical analysis of the data collected included analysis of variance (ANOVA) and stepwise linear regression.

This study provides a relatively well designed experiment, with replicates of the reefs nested together. Two different sizes of cones were deployed, and these were thus replicated within the experimental model. One feature not really considered was a control. However pre-deployment research had been carried out, and so this could be used reasonably effectively as a historical control. The study provides another design problem because of the close proximity of the sets of reef units, which are separated by only 30m of sandy bottom. Thus the individual reef units cannot be considered as independent units and so the study is based on pseudoreplicated data (Hurlbert, 1984). An issue not acknowledged by the authors.

Perhaps more pre-deployment research could have been undertaken at the sites before the deployment of the reef, as this would have allowed the impact of artificial reef deployment upon the fish aggregations of an estuary to be examined more effectively. However the study does fulfil its primary goal by assessing the factors which affect the fish aggregations associated with artificial reefs in a disciplined and quantitative manner. The visual census technique involved a diver using video/audio on 5 minute sweeps of a 5.64m diameter circle, thus providing an easily quantifiable source of data.

In terms of cost-effectiveness the study by Bortone *et al.* (1994) makes good use of the resources available, with a high number of results obtained over the 13 month study period. However, further investment in the experimental design and the deployment of more than one reef complex, would have provided a better degree of independence, and thus a true replicated design.

The study by Jensen *et al* (1994) provides a good example of the study of artificial reef colonisation using a reef which was designed to ensure a high degree of replication. The study was carried out on an artificial reef in Poole Bay deployed at a depth of around 10m below chart datum. Monitoring of the epibiotic colonisation of the reef started soon after its deployment in 1989, using photography and examination of monitoring stations on each reef module by scientific divers. Studies of the common lobster (*Homarus gammarus*, Linnaeus) and the edible crab (*Cancer pagurus*, Linnaeus) were carried out by a modified tag-recapture technique, with re-observation by divers, and acoustic tracking used. Fish studies, involved underwater videography and photography used to estimate population abundance and size of individuals, and sampling of the infauna, was carried out prior to deployment and intermittently between May 1990 and July 1991.

Within the study by Jensen *et al.* (1994) a reasonable degree of replication was achieved through the reef design, with 8 reef units being deployed. Of these 8 units, 2 replicates each of three different PFA/gypsum mixes were deployed, and two control units made of concrete. This design allowed the researchers to consider each module as an independent sample site. However, the fact that all reef modules were deployed in one area, causes a problem. The reef had been designed so that each module is a mere 10 metres away from any other reef module. Evidence of any treatment effect, for example the impact of the reef material upon colonisation, could only really be applied to the Poole Bay site without the data being pseudoreplicated. This is because of one of the definitions of pseudoreplication is, "the testing for treatment effects with an error term inappropriate to the hypothesis being considered" (Hurlbert, 1984), and so pseudoreplication is an issue which need to be carefully considered in studies of this kind.

More pre-deployment research could have been undertaken, by Jensen *et al.* (1994). This is particularly noticeable in the lobster studies, where lobster pots could have been used to sample the area, and thus begin the tagging study prior to the reef deployment, allowing the reefs impact on the lobster populations in the local area to be assessed more effectively. Also the infaunal survey suffered by having only one set of samples collected, in May 1989, prior to the reef deployment. This provides a blatant example of lack of replication in the study design, because given that the variable under test here is the impact of the reef on the infauna, one set of samples does not provide a sufficient and balanced picture of the infauna prior to the manipulation.

From the perspective of quantifying the results this study was fairly effective in the main study areas, and some qualitative data was also obtained, through the observation of reproductive/mating behaviour, and eggs laid on the reef. Thus overall a fairly effective investigation was undertaken by Jensen *et al.* (1994), and despite the initial high cost associated with the deployment of the reef, a cost-effective study was undertaken, successfully bringing together several of the main features of artificial reef colonisation. For example, their work examined the effect of reef material on epibiotic colonisation, the effect of the reefs on commercially important crustaceans (*Homarus gammarus,* Linnaeus and *Cancer pagurus,* Linnaeus) and the seasonal patterns associated with colonisation. Also the reef itself continues to provide a resource for scientific research and so the benefits associated with this should be offset against the cost.

DISCUSSION

The study of artificial reefs by scientists can be a problematic affair, which need to be carefully balanced with other interest groups, the goals of the artificial reefs and basic economics (Sayer & Wilding, 2002). This results in scientists having to make compromises, which can often affect the experimental design of their studies. This is clearly observed in the papers that were reviewed and should serve as a warning to scientists in the planning stage of any artificial reef based experiment or investigation.

In particular it was noticed that the papers reviewed often suffered from a lack of replication. This was observed most notably in the studies by Charbonnel *et al.* (2002), Fujita *et al.* (1996) and Fabi and Fiorentini (1994), where only one replicate of each test site were sampled. This causes problems in the analysis of data, because it is purely an examination of the effects on a given number of discrete sites, and so begs the question, can we apply these conclusions to artificial reefs as a whole?

In terms of pre-deployment research it was often found that prior to the deployment of an artificial reef (Jensen *et al.*, 1994), or a manipulation of an experimental reef site (Charbonnel *et al.*, 2002) that an insufficient number of samples were taken. This is most note worthy in Jensen and his colleagues work (1994), where only one set of infaunal samples were taken, and little research was mentioned on the fish and macro-invertebrate assemblages prior to reef deployment.

The level of quantitative data displayed by all five papers was high, and this indicated that quantitative studies are easily achievable in ecological field experiments of the type carried out on artificial reefs, with two of the papers also providing qualitative study. In the paper by Fabi and Fiorentini (1994) the quantitative trammel net survey was compared and contrasted with a fairly simple qualitative survey by SCUBA divers, which helped to show the bias of the trammel net against many cryptic species. Also in the paper by Jensen *et al.* (1994) some qualitative results were displayed for the number of species observed exhibiting courtship behaviour and mating, as well as any eggs observed, and this helped to provide some direction to a future investigation.

Overall in the reviewed papers the experimental design can be seen to have been inhibited mainly by the economics of artificial reef research. For instance the level of replication and quality of the experimental design was observed to be higher in the two studies which involved the deployment of experimental artificial reefs (Jensen *et al.*, 1994; Bortone *et al.*, 1994). However, in these cases the fact that the reefs were deployed in a very concentrated area caused problems. These problems are not easily resolved as reef deployment may interfere with other interest groups, e.g. the fishing industry, and may adversely affect an area of habitat, so the licensing issues of deploying a number of highly replicated reefs are likely to be prohibitively expensive and unrealistic. Further to this all the investigators would have been bound by a finite number of days when sampling work could be undertaken, because of weather, availability of ship-time, availability of divers, and the limited financial resources. As a result compromise was inevitable, and so it is easy to see how the problems highlighted by this paper arise.

In terms of "making a difference" the use of artificial reefs is effectively still in its infancy and yet their applications are already widespread, ranging from protection and aggregation of fish stocks, as an aid to the regeneration and sustainability of commercial fisheries; the mitigation of environmental damage, from as diverse sources as power stations and fish farms; to their widespread use as attractions for leisure activities, be it surfing, SCUBA diving or recreational fishing; and new applications are to be expected (Jensen, 2002).

The increased interest in artificial reef technology can only serve to expand the related scientific opportunities, as demand for increased knowledge of the functionality of reefs, and their impacts is required. However the future study of reefs will often require a multi-disciplinary approach, in order to gain a full understanding of their hydrographic, ecological and socio-economic effects and, as such the potential for scientific study should be included in the goals of any new reef, thus providing further sites where effective study can take place.

Currently the understanding of how artificial reefs impact upon the receiving environment is a limit on design, both through the disturbance caused and also through the enrichment of marine benthic habitat. It is recognised that artificial reefs are unlikely to significantly increase global marine biodiversity (Wilding & Sayer 2002a); but there is still debate over their local effects. This is largely caused by questions about the aggregation of organisms at artificial reefs, and their input back into the larval stream. The so-called attraction-production controversy (Osenberg *et al.*, 2002). In order to resolve this, several factors need to be investigated.

Firstly the effect of reef scale needs to be examined, to determine what size of reef will support a stable breeding population of a given species. This will be a difficult study to carry out because of the problems of replicating reefs on a larger scale, in terms of cost and complexity. Secondly more work needs to be carried out to establish the similarities and differences between artificial and natural reefs, by studying the similarities and differences in the community composition and relative abundance of species at a number of artificial and natural reef sites. As a result of this research, a greater knowledge of the effects an artificial reef has upon its local environment will become available. The result being the refinement of the present artificial reef applications, and a strong scientific base on which new uses for artificial reef technology can be researched and developed.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support of the Project Aware Foundation and the British Sub-Aqua Jubilee Trust. Additionally the author recognises the academic and pastoral support of both the Scottish Association for Marine Science and the University of Glasgow's Division of Environmental and Evolutionary Biology.

The author is very grateful to Dr Martin Sayer for his help, support and for providing feedback on countless copies of this review. The author would also like to thank Dr Tom Wilding, Ms Jenny Beaumont, Dr Simon Thurston and Mr Hugh Brown, for all their assistance during my years study and Dr Reudi Nager and Dr Douglas Neil for their help and advice. Multi-Beam sonar image was provided by Dr Craig Brown of the University of Ulster, and the author is extremely grateful for this courtesy.

REFERENCES

Abelson, A. & Shlesinger, Y. 2002. Comparison of the development of coral and fish communities on rock aggregated artificial reefs in Eilat, Red Sea. *ICES Journal of Marine Science*, **59**, Supplement, 122-126.

Ambrose, R.D. 1994. Mitigating the effects of a coastal power plant on a Kelp Forest Community: Rationale and requirements of an Artificial Reef. *Bulletin of Marine Science*, **55** (2-3), 694-708.

Angel, D.L. & Spanier, E. 2002. An application of artificial reefs to reduce organic enrichment caused by net-cage fish farming: preliminary results. Short Communication. *ICES Journal of Marine Science*, **59**, Supplement, 324-329.

Bortone, S.A., Martin, T. & Bundrick, C.M. 1994. Factors affecting fish assemblage development on a modular artificial reef in a northern Gulf of Mexico estuary. *Bulletin of Marine Science*, **55** (2-3), 319-332.

Charbonnel, E., Serre, C., Ruitton, S., Harmelin, J.-G. & Jensen, A. 2002. Effects of increased habitat complexity on fish assemblages associated with large artificial reef units (French Mediterranean coast). *ICES Journal of Marine Science*, **59**, Supplement, 208-213.

Clark S. & Edwards, A.J. 1994. Use of Artificial Reef Structures to rehabilitate Reef Flats degraded by coral mining in the Maldives. *Bulletin of Marine Science*, **55** (2-3), 724-744.

Collins, K.J. & Jensen, A.C. 1997. Acceptable use of waste materials. In *European Artificial Reef Research: Proceedings of the 1st EARRN conference, Ancona, Italy, March 1996*, pp. 377-360. Southampton Oceanography Centre.

Collins, K.J., Jensen, A.C., Mallinson, J.J., Roenelle, V. & Smith, I.P. 2002. Environmental impact assessment of a scrap tyre artificial reef. *ICES Journal of Marine Science*. **59**, Supplement, 243-249.

Cripps, S.J. & Aabel, J.P. 2002. Environmental and socio-economic impact assessment of Ekoreef, a multiple platform rigs-to-reefs development. *ICES Journal of Marine Science.* **59**, Supplement, 300-308.

d'Cruz, T., Creech, S., Fernandez, J. 1994. Comparison of catch rates and species composition from Artificial and Natural Reefs in Kerala, India. *Bulletin of Marine Science.* **55** (2-3), 1029-1037.

Deysher, L.E., Dean, T.A., Grove, R.S. & Jahn, A. 2002. Design consideration for an artificial reef to grow giant kelp (*Macrocystis pyrifera*) in Soutern California. *ICES Journal of Marine Science.* **59**, Supplement, 201-207.

Fabi, G. & Fiorentini, L. 1994. Comparsion between an artificial reef and a control site in the Adriatic Sea: analysis of four years of monitoring. *Bulletin of Marine Science.* **55** (2-3), 538-558.

Fujita, T., Kitagawa, D., Okuyama, Y., Jin, Y., Ishito, Y. & Inada, T. 1996. Comparson of fish assemblages among an artificial reef, a natural reef and a sandy-mud bottom site on the shelf off Iwate, northern Japan. *Environmental Biology of Fishes.* **46**, 351-364.

Grant, J.J., Wilson, K.C., Grover, A. & Togstad, H. 1982. Early development of Pendleton artificial reef. *Marine Fisheries Review*, **44**, 53-60.

Grove, R.S., Nakamura, M., Kakimoto, H. & Sonu, C.J. 1994 Aquatic Habitat Technology Innovation in Japan. *Bulletin of Marine Science.* **55** (2-3), 276-294.

Hem, S. & Avit, J.L.B. 1994. First Results on "Acadja-Enclos" as an extensive aquaculture system (West Africa). *Bulletin of Marine Science.* **55** (2-3), 1038-1049.

Hurlbert, S.A. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs.* **54** (2), 187-211

Jensen, A.C., Collins, K.J., Lockwood, A.P.M., Mallinson, J.J., Turnpenny, W.H. 1994. Colonisation and fishery potential of a coal-ash artificial reef, Poole Bay, United Kingdom. *Bulletin of Marine Science.* **55** (2-3), 1263-1276.

Jensen, A.C. 2002. Artificial Reefs of Europe: perspective and future. *ICES Journal of Marine Science.* **59**, Supplement, 3-13.

Kim, C.G. 2001. Artificial reefs in Korea. *Fisheries.* **26** (5), 15-18.

Kimmel, J.J. 1985. A new species-time method for visual assessment of fishes and its comparison with established methods. *Environmental Biology of Fishes.* **12** (1), 23-32

Lin, J.-C. & Su W.-C. 1994. Early phase of fish habitation around a new Artificial Reef off Southwestern Taiwan. *Bulletin of Marine Science.* **55** (2-3), 1112-1121.

Meir, M.H., Buckley, R., Polovina, J.J. 1989. A debate on responsible artificial reef development. *Bulletin of Marine Science* **44**, 1051-1057.

Osenberg, C.W., St. Mary, C.M., Wilson, J.A. & Lindberg, W.J. 2002. A quantitative framework to evaluate the attraction-production controversy. *ICES Journal of Marine Science.* **59**, Supplement, 214-221.

Pitcher, T.J., Buchary, E.A. & Hutton, T. 2002. Forecasting the benefits of no-take human-made reefs using spatial ecosystem simulation. *ICES Journal of Marine Science.* **59**, Supplement, 17-26.

Pratt, J.R. 1994. Artificial habitats and ecosystem restoration: managing for the future. *Bulletin of Marine Science.* **55** (2-3), 268-275.

Relini, G., Relini, M., Torchia, G. & Palandri, G. 2002. Ten years of censuses of fish fauna on the Loano artificial reef. *ICES Journal of Marine Science.* **59**, Supplement, 132-137.

Rose, C.A. 2005. Modelling and measuring the habitat complexity of artificial reefs. Ph.D Thesis. University of Newcastle Upon Tyne

Sayer, M.D.J. & Baine, M.S.P. 2002. Rigs to Reefs: A Critical Evaluation of the potential for Reef Development Using Decommissioned Rigs. *Journal of the Society for Underwater Technology.* **25** (2), 93-97.

Sayer, M.D.J. & Wilding, T.A. 2002. Planning, licensing, and stakeholder consultation in an artificial reef development: the Loch Linnhe reef, a case study. Short Communication. *ICES Journal of Marine Science.* **59**, Supplement, 178-185.

Seaman Jr., W. 2002. Unifying trends and opportunities in global artificial reef research, including evaluation. Short Communication. *ICES Journal of Marine Science*, **59**, Supplement, 14-16.

Seaman Jr., W. & Jensen, A. C. 2000. Purposes and Practices of Artificial Reef Evaluation. In *Artificial Reef Evaluation with Application to Natural Marine Habitats* (ed. W. Seaman). pp. 1-19. CRC Press.

Stephens J. & Pondella D. 2002. Larval productivity of a mature artificial reef: the icthyoplankton of King Harbor, California, 1974-1997. *ICES Journal of Marine Science.* **59**, Supplement. 51-58.

Wilding T.A. 2006. The benthic impacts of the Loch Linnhe Artificial Reef. *Hydrobiologia* **555**, 345-353.

Wilding, T.A. & Sayer, M.D.J. 2002a. Evaluating artificial reef performance: approaches to pre- and post-deployment research. *ICES Journal of Marine Science.* **59**, Supplement, 222-230.

Wilding, T.A. & Sayer, M.D.J. 2002b. The physical and chemical performances of artificial reef blocks made using quarry by-products. *ICES Journal of Marine Science.* **59**, Supplement, 250-257.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 49-56 .

SALTMARSH VEGETATION AND COASTAL PROTECTION: AN EXPERIMENTAL FLUME STUDY OF THE CORD GRASS *SPARTINA* SPP. IN THE CLYDE ESTUARY.

Gerrit Klemm[1], Alan Ervine[1], Azra Meadows[2], and Peter S. Meadows[2]
[1]Department of Civil Engineering,
[2]Division of Environmental and Evolutionary Biology, Institute of Biomedical and Life Sciences,
University of Glasgow, G12 8QQ, Scotland, UK.

ABSTRACT

Salt marshes occur on British coasts between mean high water spring tidal level and mean high water neap tidal level. They are found in sheltered regions such as estuaries and sea lochs, and consist of a slightly raised upper intertidal mud habitats colonised by salt-tolerant plants. There are a number of sites in the Firth of Clyde where salt marshes are well established, one being at Ardmore Bay, and another further up the river near the Erskine Golf Club. The Cord Grass *Spartina anglica* is a major feature of the seaward fringe of this latter saltmarsh, and is the subject of the present investigation. We have studied the effects of this species on water flow in a large laboratory flume, in an attempt to assess the species' importance in protecting this particular salt marsh, and hence by extension other salt marshes, from erosion.

Stands of the plant when studied in the flume, have a dramatic effect on the flow of water. This has also been reported by other authors in laboratory and field experiments. Our results show that the stands produce a high degree of turbulence in the water as it moves through the stand, with an associated reduction in water velocity. At the same time, water flowing either side of the stand in the flume has a significantly increased water velocity. These experiments show that *Spartina anglica* is likely to have major effects under field conditions in increasing turbulence and slowing water movement through the seaward fringe of salt marshes where it occurs. At the same time it may cause increased velocities outside the margins of the salt marsh, which in turn would potentially lead to erosion. A combined field, laboratory and modelling approach is therefore suggested.

INTRODUCTION

Salt marshes are found in temperate marine and estuarine environments, usually between mean high water spring tidal level (MHWS) and mean high water neap tidal level (MHWN). They occur in sheltered regions such as estuaries, bays, saline lagoons, and in some sea lochs. They consist of a slightly raised upper intertidal mud habitats colonised by characteristic salt-tolerant plants such as Sea Lavenders (*Limonium* spp) and Plantain (*Plantego* spp.). Several species of sedges and rushes are also common. The primary colonisers are considered to be the Glassworts (*Salicornia* spp.) and cord grasses (*Spartina* spp.). The cord grass *Spartina anglicus* is an interesting plant (Fish & Fish, 1989). It is an angiosperm and hence bears flowers. The species flowers in summer with yellow flowers on spikes. It lives in mud or muddy sand at the edge of saltmarshes, and is a primary coloniser of mud banks. It is submerged at high tide and hence is truly aquatic.

The Clyde Estuary contains a number of sites at which salt marshes have developed. These include Ardmore Point and Ardmore Bay on the north side of the estuary, and further up estuary on its south side - opposite Dumbarton Castle close to the Erskine Golf Club. This latter site contains large stands of Cord Grass *Spartina anglicus* C.E.Hubbard at the estuarine fringe of the salt marsh (Figures 1 and 2).

The current paper describes flume experiments on the protective role of *Spartina anglicus* collected from the Erskine Golf Club saltmarsh in altering water flow and turbulence. It is the first part of a study on the use of this and related species in stabilising the landward fringes of the intertidal zone in the middle and upper reaches of estuaries. *Spartina anglicus* is common in the upper reaches of the Firth of Clyde – from where our plants were collected – so our results are of direct relevance to changing river flows and rising sea level in this area, as well as having a wider relevance in temperate zone estuaries.

MATERIALS AND METHODS

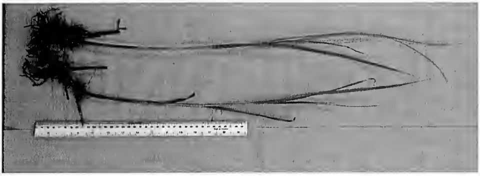
General flume description

For this study an Armfield Tilting Flume was used. The flume has a working length of 12m and a width of 0.305m. The sides of the flume are glass and 0.32m high. The bottom of the flume is made of metal with an additional layer of polystyrene, on top off which the sediment bed or other roughness elements can be placed. The working section of the flume is situated between $7< x$ [m] <11 measured from the entrance head tank. On top of the flume walls, there are railings along which a carriage is moved. The section of the flume with the vegetation is 1.70m long and starts roughly 7.70m from the entrance head tank. The flume can generate flows of up to $0.03m^3/s$.

Figure 1. The estuarine fringe of the saltmarsh at the Erskine Golf Club site. Dumbarton Rock and Castle can be seen in the distance. The large stands of *Spartina* in the centre and left of the picture are very obvious.

Figure 2. Close up view of the edge of a *Spartina* stand surrounded by mud in the same area as that illustrated in figure 1. Footprints indicate the softness of the mud.

Figure 3. Two representative plants of Spartina collected from the site shown in figure 2. The ruler is 30 cm in length.



Velocity and turbulence measurements

The velocity and turbulence measurements are carried out using a Sontek® side looking two-dimensional acoustic doppler velocimetre (2D-ADV). It measures longitudinal (x-direction) and transversal (y-direction) velocity and turbulence values. Both, velocity and turbulence measurements, are taken simultaneously.

Bed material and vegetation

The bed material used in this series of experiments is uniform sand with a d_{50} of 1mm. The bed itself has a depth of 0.07m which allows the use of the vegetation with almost its entire rooting depth. The species used for the experiments was the seagrass *Spartina anglicus* which is common at the edge of salt marshes in the upper reaches of the Clyde Estuary. The samples for this series of experiments were collected in November 2003. The samples were retrieved from the south side of the Clyde Estuary near the Erskine Golf Club, Bishopton (National Grid Reference: 243545E, 672805N. Latitude and Longitude: 55° 55' 22'' N, 04° 30' 19'' W).

The samples are taken by cutting a representative area of the same size as the space available in the flume, 1.70m by 0.30m. These samples are then transported carefully to the laboratory by vehicle. The samples are then lifted into trays to sit in the flume, leaving them in the original soil from the estuary.

Experimental procedure and setup

Before the start of the set of experiments, uniform flow is established in the flume with no vegetation. To achieve this, the flow is slowly increased to a discharge of $0.00875 m^3/s$. The water surface level is controlled using the adjustable tailgate at the bottom end of the flume until uniform flow is reached, which is determined by measuring the water surface level using a digital pointer gauge. This setup for the tailgate is kept the same for all sets of experiments. The sample of vegetation is put into the flume. At the start of each individual set of experiments the pump frequency is slowly brought up to the value of 22.5Hz to ensure the same discharge is used. Velocity and turbulence measurements are then.

RESULTS

The behaviour of Spartina in the flume is illustrated in figures 4 and 5. As the water velocity is progressively increased, the plants bend with the current, and a height difference develops between the water that is upstream of the Spartina and the water that is downstream of the Spartina. The water on the upstream side is higher than that on the downstream side. This difference is obvious in figure 5.

Water flowing over a flat surface has a characteristic boundary layer, referred to below, in which the water velocities are lower than in the main body of the water (see also appendix for definitions). For comparison purposes in this paper, the water column in the flume has been broadly categorised into water in the lower boundary layer, water in the upper boundary layer, and water above the boundary layer. This is a very generalised distinction, but is adequate for the present paper.

The velocity profiles upstream and immediately downstream of the Spartina are shown in figures 6 and 7. They are very different, and show clearly how stands of the plant significantly alter the pattern of flow. The flow upstream is a classic textbook example of flow near a smooth surface, with a well defined and smooth boundary layer (see appendix for definition). Near the bed, the velocity is slow (Figure 6 (1)). Further from the bed the velocity increases smoothly, and is approximately the same across the flume (Figure 6 (2) and (3)). It reaches a maximum just below the water surface.

Figure 4. Spartina in the flume with no water movement.

Figure 5. Spartina bending towards the left at high water velocities in the flume.

The flow immediately downstream of the Spartina is very different. It is not smooth, showing much turbulence. The flow through, over, and around the Spartina causes much turbulence (see appendix for definition) and a non-uniform flow in the lower boundary layer (Figure 7 (1)), and in the upper boundary layer and main body of the water flow (Figure 7 (2) and (3)).

A comparison of the approximate water velocities at positions 1, 2 and 3 in the upstream flow 3D profile (Figure 6) and in the downstream 3D flow (Figure 7) show significant differences. Water flow through the *Spartina* is reduced, and water flow on either side of the *Spartina* is increased, compared with upstream flow values (Table 1). In the lower boundary layer the water velocities are approximately the same upstream and down stream of the *Spartina*. In the upper boundary layer, normalised water depth of 4 to 6, there are marked differences. The water velocities in the centre of the flume upstream of the *Spartina* are 20 to 30 cm. sec^{-1} and downstream of the *Spartina* are 10 to 20 cm. sec^{-1}. The water velocities at the sides of the flume upstream of the *Spartina* are 20 to 30 cm. sec^{-1} and downstream of the *Spartina* are 40 to 50 cm. sec^{-1}. The water velocities in the water above the boundary layer show approximately the same differences between the upstream and downstream profiles as in the upper boundary layer

Figure 6. Velocity profile upstream of Spartina in the flume. 3-D plot. Note smooth profile of velocities across the flume (1 and 2), with high velocities above the bed of the flume (2, 3) which is at the bottom of the diagram. Also note the uniformity of the flow across the flume – compare 2 and 3.

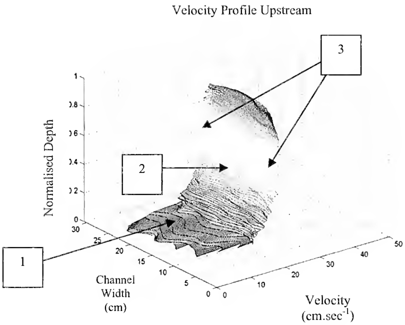


Figure 7. Velocity profile downstream of Spartina in the flume. 3-D plot. Current velocity is slow in the centre of the flume through the Spartina (1 and 2), and fast at the edges of the flume on either side of the Spartina (3). Note confused profile of velocities indicating a high degree of turbulence.

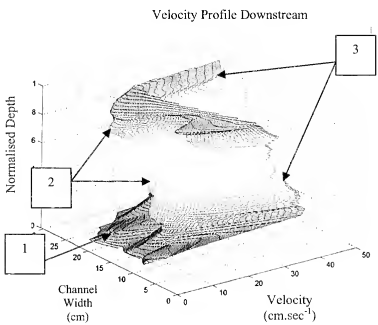


Table 1. Comparison of water velocities upstream and immediately downstream of the *Spartina* in the flume. Velocities are approximate, as they are obtained from figures 6 and 7 by interpolation.

	Water velocities upstream of the *Spartina* (cm. sec^{-1})		**Water velocities downstream of the *Spartina* (cm. sec^{-1})**	
	Centre of flume	**Sides of flume**	**Centre of flume**	**Sides of flume**
Lower Boundary Layer (1) (normalised water depth 0 to 3)	5 - 20	5 – 20	5 - 15	5 - 15
Upper Boundary Layer (2), (3) (normalised water depth 4 to 6)	20- 30	20 – 30	10 - 20	40 - 50
Water above the boundary layer (2), (3) (normalised water depth 6 to 8)	30 - 40	30 – 40	10 - 20	40 - 50

DISCUSSION

With increasing threats of climate change, global warming and sea level rise, coastlines are becoming vulnerable to erosion and flooding. A major concern ahead is to devise measures to protect our shorelines, by coastal defences and possibly by greener and softer methods, and there is a rapidly developing literature. Vegetation has been shown to alter water flow, enhance deposition of sediments and soils, and hence promote stabilisation by slowing down erosion (Boon, 1975; Bayliss-Smith et al., 1979; Healey et al. 1981; Hull, 1987; French & Stoddart, 1992; Fonseca, et al. 1982, 1983; Eckman, 1983; Stumpf, 1983; Fonseca, & Fisher, 1986; Gambi, et al. 1990; Wang, et al., 1993; Isaksson et al., 1994; Leonard & Luther 1995; Shi *et al.*, 1995, 1996; Ikeda & Kanazawa 1996; Allen, 1997; Boorman et al., 1998; Koch & Gust, 1999; Nepf, 1999; Nepf & Koch 1999; Sfriso et al., 2001; Romano *et al.*, 2003; Neumeier & Ciavola, 2004; Bouma *et al.*, 2005; Naden *et al.*, 2006). These studies were the starting point for the present investigation.

Nationally, salt marshes represent a significant part of the boundary between the land and brackish water in estuaries, and between the land and the sea along near-shore coastal seas. There are 32500 hectares in England, 6747 hectares in Scotland, 6098 hectares in Wales and 215 hectares in Northern Ireland. Approximately 80% of these have been designated Sites of Special Scientific Interest (SSSI's).

In the United Kingdom generally, common threats to saltmarshes include urbanisation and land claim for agriculture, industry, ports, harbours, barrages, link roads, marinas and waste disposal. Grazing of cattle on salt marshes also occurs, and this can cause considerable damage if not carefully controlled. Coastal erosion also affects saltmarshes, and the loss here is thought to be of the order of 100 hectares per year nationally.

Although there are a number of saltmarshes in the Firth of Clyde including the one studied in this paper, the largest one in Scotland is in the Solway Firth. This provides shelter and food for a large number of wildfowl and waders in winter and is the sole site at which the natterjack toad occurs. Scottish Natural Heritage (SNH) has developed 'The Merse Management Scheme' in Solway, which encourages farmers to use traditional grazing practice, thus limiting loss of local biodiversity. All of this means that any investigation aiming on the one hand to preserve salt marshes and on the other to use them in order to protect the coastline is very apposite.

Many of the papers referred to above are relevant to our own investigations. However we wish to refer to three of the more recent ones. Shi et al., (1995, 1996) measured water velocities within and above canopies of *Spartina anglica* in a flume, while the present study examined velocities upstream and downstream of canopies of *Spartina anglica*. Hence Shi et al., (1995, 1996)'s results are not strictly comparable with ours. However they are interesting. In their laboratory investigations Shi et al., (1995, 1996) used stems of *Spartina* which were attached through holes to a concrete plate (0.6m^{-2}), at an even spacing. Five heights of canopy were used: 30cm, 24cm, 18cm, 12cm, and 6cm. The stems were cut to four heights, 80%, 60%, 40% and 20% of the original canopy height of 30 cm, resulting in five heights in all. These were tested in a flume. Above the canopy, the velocity profiles were J shaped, suggesting that the flow above the canopy was typical of turbulent boundary layer flow (see appendix). This effect became more pronounced as the canopy

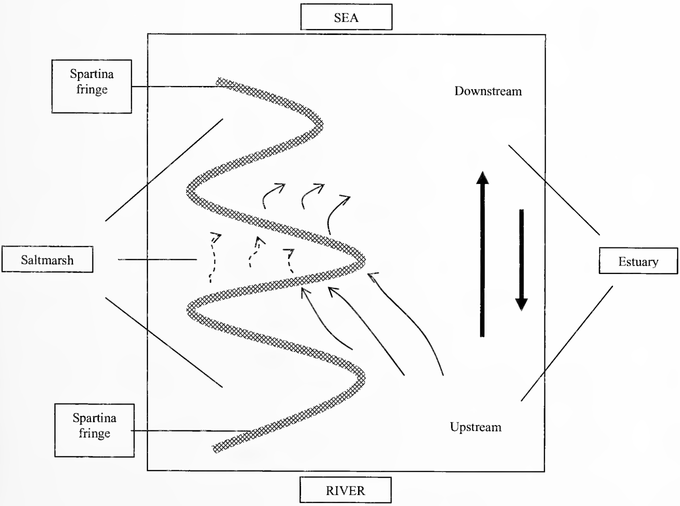
height was reduced. Mean water velocities within the five stands were 0.051, 0.049, 0.028, 0.038 and 0.033 $m.s^{-1}$. In other words slower velocities occurred in lower canopies. The current authors would have expected that slower velocities would have occurred in higher canopies. Shear velocity was reduced in the canopies. This would favour sediment deposition.

In a separate field study, Bouma *et al.*, (2005) measured velocity profiles and turbulence in *Spartina* beds, working from the sediment bed upwards, into and above the canopy. Their results show that the current velocities were a magnitude lower in the canopy than on the mudflat. This is broadly similar to our flume observations showing that velocities are decreased by Spartina stands, while at the same time turbulence is increased.

Our field observations and laboratory studies on stands of the cord grass *Spartina anglica* are therefore of significance not only to the Firth of Clyde, but to any area where this species is a major constituent of the saltmarsh fringe. A detailed study of the behaviour of the species is now required, comparing studies under laboratory conditions, with conditions in situ in the field at the same site from which plants are collected. The salt marsh near the Erskine Golf Club would be ideal for this study. It is easily accessible, and close to laboratory facilities at the University of Glasgow.

We have also begun to explore the generalised influence of Spartina stands fringing salt marshes such as that investigated in the present study To this end we provide the diagram shown in figure 8, in order to provide a pictorial image for modelling. The edge of the salt marsh is wavy, as it is in the field near the Erskine Golf Club (Figures 1 and 2). This implies a periodic forcing by the ebb and flow of the tide, and requires investigation. The shape of the curve indicates that the stands of Spartina will act like headlands, deflecting the flow of water. There are also likely to be eddies and swirls downstream of the flow of water that are reminiscent of Von Karman vortices. A combined laboratory, field and modelling approach is therefore likely to be rewarding.

Figure 8. Diagram of the edge of a salt marsh similar to that at Erskine Golf Club, Bishopton.
See figure 1 and 2. Thick vertical lines: main ebb and flow of the tide combined with river flow. Thin lines: ebb-tide local water flow towards and away from the edge of the saltmarsh. Thin wavy dashed lines in the saltmarsh, slow turbulent flow within the salt marsh itself. Water flowing away from the salt marsh is slower and more turbulent. Thick hatched wavy line: edge of the saltmarsh made up of stands of Spartina plants (Spartina fringe). Thin wavy dashed lines in the saltmarsh, slow turbulent flow within the salt marsh itself.



ACKNOWLEDGEMENTS

The authors are most grateful to Stuart MacLean, Department of Civil Engineering, University of Glasgow for his advice and practical help with the operation of the flume. The practical work reported in this paper forms part of Gerrit Klemm's PhD thesis, University of Glasgow.

REFERENCES

Allen, J.R.L. 1997. Simulation models of salt-marsh morphodynamics: some implications for high-intertidal sediment couplets related to sea-level change. *Sedimentary Geology,* **113**: 211–223.

Bayliss-Smith, R.P., Healey, R.G., Lailey, R., Spencer, T., & Stoddart, D.R. 1979. Tidal flows in salt marsh creeks. *Estuarine, Coastal and Marine Science* **9**: 235-255.

Boon, J.D. III 1975. Tidal discharge asymmetry in a salt marsh drainage system. *Limnology and Oceanography* **20**:71 80.

Boorman, L.A., Garbutt, A. & Barratt, D. 1998. The role of vegetation in determining patterns of the accretion of salt marsh sediment. *In*: Black, KS; Paterson, DM, and Cramp, A. (eds.), *Sedimentary processes in the intertidal zone.* Geological Society (London), Special Publication No 139, pp. 389–399.

Bouma, T.J., De Vries, M.B., Low, E., Kuster, L., Herman, P.M.J., Tanczos, I.C., Temmerman, S., Hesselink, A., Meire, P. & van Regenmortel, S. 2005. Flow hydrodynamics on a mudflat and in salt marsh vegetation: identifying general relationships for habitat characterizations. *Hydrobiologia* **540**: 259-274.

Eckman, J.E. 1983. Hydrodynamic processes affecting benthic recruitment. *Limnology and Oceangraphy* **28**:241-257.

Fish, J.D. & Fish S., 1989. *A Student's Guide to the Seashore*. Unwin Hyman. London.

Fonseca, M.S. & Fisher, J.S. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. *Marine Ecology Progress Series* **29**:15–22

Fonseca, M.S., Fisher, J.S., Zieman, J.C., and Thayer, G.W. 1982. Influence of the seagrass, *Zostera marina* L., on current flow. *Estuarine, Coastal and Shelf Science* **15**:351-364.

Fonseca, M.S., Zieman, J.C., Thayer, G.W., and Fisher, J.S. 1983. The role of current velocity in structuring seagrass meadows. *Estuarine, Coastal and Shelf Science* **17**:367-380.

French, J.R. & Stoddart, D.R. 1992. Hydrodynamics of salt marsh creek systems: Implications for marsh morphological development and material exchange. *Earth Surface Processes and Landforms* **17**:235-52.

Gambi, M.C., Nowell. A.R.M., & Jumars, P.A. 1990. Flume observations on flow dynamics in *Zostera marina* (eelgrass) beds. *Marine Ecology Progress Series* **61**:159–169.

Healey, R.G., Pye, K., Stoddart, D.R., & Bayliss-Smith, T.P. 1981. Velocity variations in salt marsh creeks, Norfolk, England. *Estuarine, Coastal and Shelf Science* **13**:535-545.

Hull, S.C. 1987. Macroalgal mats and species abundance—a field experiment. *Estuarine and Coastal Shelf Science* **25**:519–532.

Ikeda, S., & Kanazawa M 1996. Three dimensional organized vortices above flexible water plants. *Journal of Hydraulics Engineering* **122**:634–640.

Isaksson, I., Pihl, L., & Vanmontfrans, J. 1994. Eutrophication related changes in macrovegetation and foraging of young cod *(Gadus morhua* L.)—a mesocosm experiment. *Journal of Experimental Marine Biology and Ecology* **177**:203–217.

Koch, E.W. & Gust, G. 1999. Water flow in tide- and wave dominated beds of the seagrass *Thalassia testudinum. Marine Ecology Progress Series* **184**:63–72.

Leonard, L.A. & Luther, M.E. 1995. Flow hydrodynamics in tidal marsh canopies. *Limnology and Oceanography* **40**:1474–1484.

Naden, P, Rameshwaran, P., Mountford, O., & Robertson, C. 2006. The influence of macrophyte growth, typical of eutrophic conditions, on river flow velocities and turbulence. *Hydrological Processes* **20**: 3915–3938

Nepf, H.M. 1999. Drag, turbulence, and diffusion in flow through emergent vegetation. *Water Resources Research* **35**: 479–489.

Nepf, H.M. & Koch, E.W. 1999. Vertical secondary flows in submersed plant-like arrays. *Limnology and Oceanography,* **44**: 1072–1080.

Neumeier, U. & Ciavola, P. 2004. Flow resistance and associated sedimentary processes in a Spartina maritime saltmarsh. *Journal of Coastal Research* **20:** 435-447.

Romano, C., Widdows, J, Brinsley, M.D. & Staff, F.J. 2003. Impact of Enteromorpha intestinalis mats on near-bed currents and sediment dynamics: flume studies. Marine Ecology Progress Series 256: 63-74.

Sfriso A., Birkemeyer, T. & Ghetti, P.F. 2001. Benthic macrofauna changes in areas of Venice lagoon populated by seagrasses or seaweeds. *Marine Environmental Research* **52**:323–349.

Shi, Z., Pethick, J.S., Burd, F. & Murphy,B. 1996. Velocity profiles in a salt marsh canopy. *Geo-Marine Letters,* **16:** 319–323.

Shi, Z., Pethick, J.S. & Pye, K. 1995. Flow structure in and above the various heights of a saltmarsh canopy: a laboratory flume study. *Journal of Coastal Research* **11**:1204–1209.

Stumpf, R.P. 1983. The processes of sedimentation on the surface of a salt marsh. *Estuarine, Coastal and Shelf Science* **17**:495-508

Wang, F.C., Lu, T.S., & Sikora, W.B. 1993. Intertidal marsh suspended sediment transport processes, Terrebonne Bay, Louisiana, USA. *Journal of Coastal Research* **9**: 209-220

Glasgow Naturalist 2006. Volume 24. Part 4. Page 57.

APPENDIX TO:
SALTMARSH VEGETATION AND COASTAL PROTECTION: AN EXPERIMENTAL FLUME STUDY OF THE CORD GRASS *SPARTINA* SPP. IN THE CLYDE ESTUARY. Gerrit Klemm, Alan Ervine, Azra Meadows, and Peter S. Meadows.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 49-56 .

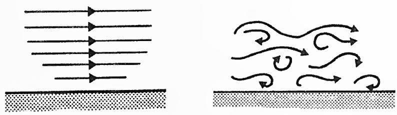
TURBULENT FLOW, LAMINAR FLOW, AND THE BOUNDARY LAYER.

Azra Meadows and Peter S Meadows
Division of Environmental and Evolutionary Biology,
Institute of Biomedical and Life Sciences,
University of Glasgow, G12 8QQ.
gbza31@udcf.gla.ac.uk

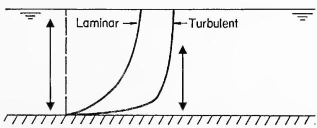
Water flowing in any natural or artificial body of water is either flowing in a turbulent manner or in a laminar manner. The mathematical definitions of these two flow regimes are straight forward, but need not concern us here (c.f. Simons, 1969; Harvey, 1976). Appendix figure 1 illustrates the difference between the two. In laminar flow, the particles of water are flowing in an orderly fashion in one direction - the direction of overall flow. In turbulent flow, the particles of water are flowing in a number of directions with little apparent order, although the flow is overall in one direction – in the figure towards the right.

A boundary layer exists when any water mass is flowing over a solid surface. The mathematics are fairly straight forward, but again need not concern us (c.f. Simons, 1969; Harvey, 1976). The water velocity in this boundary layer is less than in the main body of the water, and approaches zero as the solid surface is approached. Appendix figure 2 illustrates typical boundary layers for water flowing in a laminar and in a turbulent manner. The two curves are slightly different. The height of the boundary layer is defined as the height above the solid surface at which the water velocity becomes equal to the water velocity in the main body of the water mass. This is illustrated in the figure by the two double-headed arrows, the left hand one referring to the boundary layer for laminar flow, and the right hand one referring to the boundary layer for turbulent flow.

Appendix Figure 1. Left diagram: Laminar Flow. Right diagram: Turbulent Flow. From Harvey (1976).



Appendix Figure 2. Boundary layer flow of a liquid above a flat solid surface under laminar conditions (left hand curve) and under turbulent conditions (right hand curve). X axis velocity. Y axis = distance above the flat solid surface. The double headed arrow to the left of the laminar flow velocity profile = the depth of the laminar flow boundary layer. The double headed arrow to the right of the turbulent flow velocity profile = the depth of the turbulent flow boundary layer. From Simons (1969).



Harvey, J.G. 1976. *Atmosphere and ocean: our fluid environments. Artemis*, Sussex.
Simons, D.B. 1969. Open Channel Flow. Ch 7 in *Introduction to Physical Hydrology*. Edit R.J. Chorley. Methuen & Co. Ltd. London.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 59-71 .

FROM GLASGOW TO THE STAR PIT AND STUTTGART: A SHORT JOURNEY AROUND THE WORLD'S LONGEST FISH

Jeff Liston

Graham Kerr Building, Division of Environmental and Evolutionary Biology,
Faculty of Biomedical and Life Sciences,
and
Hunterian Museum,
University of Glasgow, Glasgow, G12 8QQ

ABSTRACT

The Ferrier Fergusson family of Glasgow's West End are more commonly known for their connections to the Tennant family – Henrietta Fergusson and her cousin Margaret Galbraith both married the Tennant brothers who founded the chemical company in their name (Crathorne, 1973). But the sister of Henrietta, Mary Ferrier Fergusson (or 'Ferry' as she was known to her family), married Alfred Nicholson Leeds of Eyebury near Peterborough, who was to become the single collector of the most extensive collection of Jurassic marine reptiles ever. As well as supporting and tolerating the invasion of Alfred's hobby into their living space, Mary also assisted him with the reconstruction of the often fragmentary fossil remains. Her efforts are in particular noted, with regard to the tail of the bony fish *Leedsichthys problematicus* (named in Alfred Leeds' honour), which it took them some nine months to glue together from its thousands of excavated fragments (Leeds, 1956). Following Alfred's death in 1917, Mary requested that the remainder of his collection go to her native city, as part of the Hunterian Museum's collections. Included within the material acquired by the Hunterian from the Leeds family is a singularly complete specimen of the fish *Leedsichthys problematicus*, which currently forms the basis of a research project (in part financially supported by the Glasgow Natural History Society's Blodwen Lloyd Binns Bequest fund) into the osteology of this animal. After the commencement of this project, a new specimen was discovered near Peterborough, which has been included within the scope of this work. Nicknamed 'Ariston', this specimen is the first significant find of this animal in Britain in ninety years.

INTRODUCTION

The nineteenth century was a crucible for change. From historical assessments of ancient cultures, to philosophical viewpoints of the universe, many fields were being critically reassessed in the light of new understanding. Even within the Church, voices were raised questioning the literal truth of the Bible, in the controversial 1860 collection of 'Essays and Reviews' by a series of Anglican clerics and theologians (Blackmore & Page, 1989). New feats of engineering and industrialisation were similarly paralleled by changes in theories of the natural world – advances in microscopy had led to new studies and understanding of biological tissues (Liston & Sanders, 2005). The expanding science of palaeontology was starting to pose awkward questions about the natural world in terms not only of the mutability of species, but also of the extinction of species – something that did not sit comfortably with the majority of people's religious beliefs, and their perception of the Great Chain of Being. The cautious assertion by individuals in the eighteenth century that some animals had become extinct (Rolfe, 1985), had led to the instinctive strivings of Chevalier de Lamarck's *Philosophie Zoologique* (Lamarck, 1809) and Robert Chambers' *Vestiges of the Natural History of Creation* (Chambers, 1845). But these ideas were finally cogently expressed in Darwin's *On the Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (Darwin, 1859). Darwin had been berated for the lack of a fossil example of an intermediate animal between two groups (or 'missing link') to demonstrate his theory of organic evolution 'in action' in the fossil record – but within three years the London specimen of *Archaeopteryx* had been revealed to the world, appearing to provide just what Darwin was lacking (Liston, 2000). Increasingly, the scientific world appeared to be moving towards a worldview that had no need of recourse to a deity working towards a 'grand plan', 'intelligent design' or 'final cause'.

Although it received little coverage at the time, the public debate between Archbishop Wilberforce ('Soapy Sam') and Thomas Henry Huxley on 30th June 1860 at the British Association for the Advancement of Science meeting in Oxford has subsequently come to be seen as symbolic of some of the wrenching changes that the Victorian world was going through at the time. In attacking Darwin's work, Wilberforce is alleged to have sarcastically asked Huxley if he was descended from an ape on his maternal or paternal grandparent's side – after countering Wilberforce's objections, Huxley then accused the Archbishop of prostituting his gifts of eloquence in order to undermine a serious scientific discussion: for a clergyman to be taken so publicly to task was indeed a sign that Science was in the ascendancy (Blackmore & Page, 1989). The debate seems to have signalled a shift in focus away from extinction to questions of descent. And as a symbol of the struggle that society was undergoing, the debate has a deeper resonance than that, for the foundations of its venue (the debate was the public inauguration of a building – the Oxford University Museum - paid for, somewhat ironically, with surplus funds from the University Press's Bible account! (Thomson, 2000)) were sunk deep into the Oxford Clay – one of the most highly vertebrate rich fossil sediments of the British Isles, replete with the remains of extinct animals awaiting discovery.

THE OXFORD CLAY

To the northeast of Oxford, but still within this same rich fossiliferous sediment, was a geographical area in which great surges in knowledge of ancient animal life were to be symbiotically linked with parallel industrial development - the Fenland around Peterborough. It began with an auctioned sale of land around Fletton (just south of Peterborough) – 400 acres were sold on 23/6/1877, and a series of individuals from a diverse group of trades decided to try their hand at producing bricks from the 'brick clay' of this land. Within four years, it had been noted that the deeper clay of the Peterborough area (the Lower Oxford Clay, lying beneath the superficial callow clay more traditionally dug) had an extremely high organic content, which meant that no additional coal or carbon was needed to be imported to fire the bricks – in essence, this 'clay that burns' was self-firing, and in removing the need for the additional expense of shipping in coal for the kilns, Fletton bricks became significantly cheaper, and thus hugely popular. It was this that changed the trend of clay digging from being a small-scale (often family-based) seasonal business, to a large-scale year round industrialised process. This meant that even more land around Peterborough came up for sale, and the landscape was swiftly transformed, with forests of kiln chimneys strewn across the landscape. Although initially excavated by hand with teams of men wielding 2 metre crowbars, this gradually gave way with the rise in demand from 1890 to industrial machinery and mechanical excavators, which more or less dominated the few pits that remained active during the Great War (Hillier, 1981).

By and large, it is essential for human (rather than mechanised) diggers to be employed to dig the clay, in order to observe fossils as they appear and prevent them from being destroyed during clay excavation - as noted by the renowned palaeontologist W. E. Swinton (in the foreword to Leeds, 1956). From this point of view, the optimum historical period for retrieval of fossils, is defined by the peak period of clay excavation following the realisation that the Lower Oxford Clay is an exceptionally useful for brick manufacture (circa 1881), until the time that the industry switches to being fully mechanised, around the end of the war (Leeds, 1956). Throughout this period, one key figure was abroad in Peterborough, collecting the marine fauna from the Jurassic seabeds represented by the Oxford Clay. He had collected such material in earlier years prior to large-scale excavation, and now he was poised to take advantage of the wealth of new material being uncovered every day by the armies of clay diggers now employed in the region. His name was Alfred Leeds.

ALFRED NICHOLSON LEEDS AND MARY FERRIER FERGUSSON

On Tuesday 19th October, 1875, a marriage took place at 11, Grosvenor Terrace (Fig. 1), Glasgow, between the young daughter of city merchant Alexander A. Fergusson, and Alfred Nicholson Leeds Fig. 2), a gentleman farmer living on the fens east of Peterborough. Mary Ferrier Fergusson was embarking on a wedded relationship with a man destined to become one of the world's greatest collectors of fossil Jurassic reptiles. She would also be, in equal part, a preparator and conservator of the bones of these animals from the Middle Jurassic Oxford Clay. In the twenty fifth year of their marriage (as recorded by the second of their five sons, Edward Thurlow Leeds (Leeds, 1956)), they spent nine months in cleaning and gluing together the many thousands of fragments that made up the tail of what was certainly the largest ever bony fish, *Leedsichthys*, named in honour of her husband (Fig. 4). Her palaeontological contribution thus went far beyond the perhaps typical one of the wife of a palaeontologist in the nineteenth century, because beyond simply tolerating the array of drawers of bones strewn around the many rooms of their house in Eyebury (Fig. 3) (east of Peterborough) while they were being worked on by her husband, she was an active supporter and collaborator in his work. Indeed, when Alfred Leeds died on the 22nd August 1917, it became necessary for the family to leave Eyebury soon after, and so she took a hand in the final disposal of the last accumulation of his collection, expressing the wish to Thurlow Leeds that the remainder of the collection of her dead husband (some 450 marine reptile specimens), pass into the care of the University of Glasgow, her native city. This led to the University of Glasgow's Hunterian Museum becoming the owner of the largest collection of Jurassic reptiles from a single collector in Britain, second only in size to the British Museum (Natural History), London.

This was a prodigious achievement: although the British Museum had, during Alfred's lifetime, been the main beneficiary of his collecting, having first refusal on any of the material that he found, most of the material that the British Museum had declined had passed through the hands of the dealer Stürtz of Bonn (between 1897 and 1911), to spread not simply throughout Europe, but around the globe (Leeds, 1956). The Hunterian's acquisition of this final bulk component of his collection meant that, in numerical terms at least, the Hunterian held the largest single collection of Alfred Leeds' material in the world. By the time of this purchase, the Hunterian Museum, along with the rest of the University of Glasgow, had moved from its Old College city centre site into Glasgow's West End, some 5 minutes walk from where Alfred and Mary had married, in Mary's family's home of 11, Grosvenor Terrace, at the head of Byres Road. This meant that for any future trips she made to see her family in Glasgow, the Museum holding the collection from over twenty five years of her late husband's collecting, would be near at hand to visit – and indeed the Hunterian Museum's visitor books record one of her visits on the 21st September 1915.

Prior to this final sale, however, some connections had already existed between Alfred Leeds and the University of Glasgow. A few modest batches of fossil material had already been bought from Leeds by Professor John Walter Gregory (see Fig. 5), the Head of the Geology Department. Gregory appears to have first come into contact with the Leeds Collection when he started work as an Assistant in the Geology Department of the British

Museum (Natural History) in 1887 (Longwell, 1933), during the period in which the initial bulk purchase ('The First Collection') from Alfred Leeds was arriving in that establishment (Leeds, 1956). Gregory later became the first incumbent of the Chair of Geology at Glasgow University in 1904. With that post came the Honorary Curator-ship in Geology for the University's Hunterian Museum, and it was after this that he arranged the purchases for the Hunterian's collections. Included within these were a remarkably complete skeleton of the ichthyosaur *Ophthalmosaurus*, (assembled by Assistant Curator William Robert Smellie, Fig. 6, so that it was on display in the Hunterian Museum from around 1916 until the 1970s, see Fig. 7), and what later turned out to be the most complete specimen of *Leedsichthys* ever collected (Liston, 1999). Now nicknamed 'Big Meg' (Fig. 8), this specimen was first noted by Alfred Leeds in a letter to Arthur Smith Woodward in February 1913 (Leeds, 1913) (Fig. 9, Fig. 10), and was sold to the University of Glasgow in February 1915 (Liston, 2004). Given that Alfred Leeds had traditionally offered first refusal of all his specimens to the British Museum (Natural History) in London, it may seem strange that the BM(NH) did not take the opportunity to purchase this specimen, as it consisted of more than twice the quantity of material as their holotype specimen (BMNH P6921), but archival documentation in the NHM appears to indicate that they had bought a substantial specimen from Alfred Leeds some fifteen years earlier – a specimen that now (despite its size) cannot be entirely confidently located (Liston, 2004; Liston & Noè, 2004). In the light of this, it is perhaps understandable that the BMNH might have let this particular fish 'get away' to Glasgow.

'Meg' is currently the core specimen of a research project based at the University of Glasgow, investigating the virtually undescribed osteology of *Leedsichthys*. To support this research, virtually all known specimens of this taxon have been loaned to Glasgow, a loan that was made financially possible through a generous grant from the Glasgow Natural History Society's Blodwen Lloyd Binns Bequest. The bones of this animal are renowned for being extensive, crushed, broken and fragmentary. In 1889, Arthur Smith Woodward made tentative attempts to understand its skull osteology (Woodward, 1889a, 1889b, 1890), but admitted eight years later that beyond the fin-rays of the tail and the seven and a half centimetre long gill rakers, that no bone had been satisfactorily identified (Leeds & Woodward, 1897). It is believed, because of the unsegmented and bifurcating nature of the fin rays in its tail, that this fish is a member of the Family Pachycormidae. Indeed, in 1916 (Woodward, 1916), Arthur Smith Woodward himself stated with some excitement that he could see a resemblance to *Leedsichthys* bones "in miniature" in the 1.5 metre long specimen of the pachycormid *Saurostomus* from the Holzmaden shale (BMNH P11126, Fig. 11). Arguably the best collection of Jurassic fossil fish specimens lie in the museums in Germany with substantial material from the Holzmaden Posidonienschiefer or lower Jurassic shale of southern Germany, and so a collection visit to these museums (again, generously supported by a grant from the Glasgow Natural History Society's Blodwen Lloyd Binns Bequest) became an essential part of the study.

Why try to see a large number of specimens, as opposed to one well-preserved individual? There are a number of reasons why a comprehensive attempt to see as many specimens as possible of this family of bony fishes would be vital to understanding the skeletal anatomy of *Leedsichthys*, but the central one is this: the skull bones of these pachycormids are so thin and interlock and overlap to such a degree, that individual bones (such as remain of *Leedsichthys*) are extremely hard to discern: it is no surprise that if one looks at the smaller but apparently related genus of *Saurostomus* from the Holzmaden shales that its skull bones are like silk handkerchiefs, so thin that it is hard to tell which bone is lying on top of which (Fig. 12). It is thus only through examining specimens showing skulls in widely differing degrees of disarticulation, that individual bones (and their origins within the overall scheme of the skull) can be determined. Thus, after a few interesting hints from other institutions across Germany (in particular in München and Tübingen), it was of little surprise that the most important clues to the identities of some of the giant skull bones of *Leedsichthys* came from the remarkable Staatliches Museum für Naturkunde in Stuttgart, with its many specimens of both *Pachycormus* and *Saurostomus* from the Holzmaden shale. For the first time, as a result of this examination, it was clear that bones extremely similar to the maxillary (Fig. 13) and dentary (Fig. 14) bones of *Saurostomus* were present in large form in some of the remains of *Leedsichthys* (Fig. 15, 16).

But a more direct aid to the understanding of the skeletal anatomy of *Leedsichthys* had also come to light in the interim.

LEEDSICHTHYS - A NEW SPECIMEN

In July 2001, I received a bone through the post. Not an entirely unusual event in itself, this bone would turn out to be something quite special. It had been found by a Portsmouth Palaeobiology undergraduate (Martill, 2002), working in one of the many brick pits around Peterborough that excavate the Oxford Clay to manufacture bricks (Dawn, 2004). The student, Marcus Wood, had come across the bone protruding from a face that had not been worked by the shale planer since the early nineteen eighties. Another student on the course, Matt Riley, looked at the face independently, and saw a number of smaller bones protruding from the same bed. Fortunately, their course supervisor, Dr. David M. Martill, was also, in collaboration with Dr. Colin Adams of the Institute of Biomedical and Life Sciences, University of Glasgow, co-supervising my postgraduate research on the gigantic Jurassic fish *Leedsichthys*, and so knew to send the bone to me for identification. I was able not only to confirm his suspicion that it was indeed *Leedsichthys*, but also to state that it was likely to be a dorsal fin spine, of the kind mistakenly identified by the German palaeontologist Von Huene as being a tail spine belonging to the stegosaurian dinosaur *Omosaurus* (now *Lexovisaurus*) (Huene, 1901) (see Fig. 17).

The Star Pit at Whittlesey (coincidentally one that Alfred Leeds had himself collected from some 90 years before) was coming to the end of its working life, producing clay for the Hanson Brick Company to turn into bricks. This meant that if a dig were to be organised, it could be run without the health and safety issues surrounding the excavation of material in the same pit as active shale planers, which could prove potentially dangerous. Dr. Martill and myself made plans, and eventually visited the site on the 22nd October 2001, together with Alan Dawn of the Peterborough City Museum, to assess the significance of the find and the potential of the site. We had mixed results from the assessment – on the positive side, we could confirm that, as Matt Reilly had indicated, there were 13 small bones projecting from the cliff, over an 8.5 metre stretch of the same layer (Bed 14 (Hudson & Martill, 1994)) as the one that had yielded the longer dorsal fin spine (Fig. 18). Given the range in sizes of the projecting bones, and that the remains seemed relatively concentrated for a fish estimated to grow anywhere from 10 (Woodward, 1917) to potentially 27.6 metres (as hinted at in the case of one exceptional partial set of remains (Martill, 1986)), it seemed that little transportation or disruption to the skeleton had occurred. This appeared to indicate that a major find, as large as any specimen so far recovered, was hidden within the cliff. On the negative side, an excavation could not be conducted particularly far into a bed with 20 metres of overburden with very much safety. And given the size of the fish, both Dave and I knew that it was likely that a substantial area of the cliff would have to be removed to be confident that we had a chance of recovering everything that we both felt might well be there. It was clear that this would require a heavy piece of excavating machinery, and this would not be cheap to hire. In the worst possible case scenario, we might end up spending a large amount of money to remove a cliff some 20 metres (50 feet) in height, only to find that the fragments that we could see the ends of, were all that was left of the fish – the rest having been removed in the early 1980s and turned into bricks perhaps used for a bathroom extension in Norfolk in the nineteen eighties. But this seemed the least likely result. What was virtually certain was that we had the most significant find of this fish since (according to Natural History Museum archives) February 1913 (Leeds, 1913), and what was extremely likely was that within the cliff was probably the most complete specimen of the fish ever found.

What made attempting to excavate the specimen all the more worthwhile, was that one had never been excavated under the rigour of full scientific procedures, with mapping of the remains before they came out of the ground. The closest to mapped indications of how the bones of *Leedsichthys* had been found, were some doodled sketches contained in a letter from the collector Alfred Leeds to Arthur Smith Woodward of the British Museum (Natural History) in London (Leeds, 1898), and a rough scale-less site map made up retrospectively by a group of German teenagers (as well as Peterborough, the remains of the fish have also been found in Normandie, northern Germany, and Chile) analysing fifteen years worth of photographs that they had taken during their digs (Probst & Windolf, 1993; Michelis *et al.*, 1996). Even if we did prove to be misguided in our expectations of the completeness of this new specimen, the value of the first properly mapped record of the bones of *Leedsichthys* as found, could be immeasurable.

The rarity of such an opportunity was too great to pass on, and by May 2002 Dr. Martill had raised the initial funding for a 2-week dig, led by myself, scheduled for the following month. Dr. Martill would have led the dig himself, but for his intensive work schedule for that summer. Personally, my schedule was also busy - I had a long-planned tour of collections in Germany booked for July - but given the quantity of bone likely to be excavated (based on the quantity of material comprising the most complete specimen currently known, the specimen nicknamed 'Big Meg' in the University of Glasgow's Hunterian Museum), the planned two weeks would be adequate for the excavation necessary. Unfortunately, paperwork problems delayed our starting date, so that the heavy excavator, a 21 tonne Komatsu, could only get access to the site starting on the 24th June (Martill & Liston, 2003). It took fully five days for the extremely skilled driver, Dave Peppercorn, to remove the 20-metre overburden from a roughly 25 metre by 9-metre area of the bed (Fig. 19). He was able to strip the clay beds back to a yellow shell bed layer some 8cm above the bone level (Dawn, 2002), shifting some 10,000 tonnes of material in the process, some of which went to form a platform and slope that our volunteer diggers would later use to work on.

The sky was darkening when the Komatsu excavator finally left the site at the end of that first week, its job done (Fig. 20). I remained to guard the dig over the weekend, to ensure that no opportunistic collectors tried to scavenge material from an abandoned site, while Dr. Martill went to collect his undergraduate volunteer diggers from Portsmouth University for the following Monday morning. I was able, in the fresh 8am daylight of that first Saturday morning, to go down to the newly exposed bed, start to excavate from the edge of the cliff, and take stock of what we actually had. I will never forget that initial period of excavation, seeing the enormous density of bone, far in excess of what we had seen protruding from the edge, and way beyond our expectations. It was clear that we had at least one very completely preserved section of this fish (Fig. 22). Some faulting within the cliff (resulting from slippage of the cliff after being worked by the shale planer in the early eighties) meant that the bone might be limited to that first area (Fig. 21), but still the quantity of bone recovered had already made the expenditure on the excavator worthwhile.

Two days into the following week, I was already running behind schedule for my planned departure for the collection study trip (including the valuable and successful visit to Stuttgart, mentioned earlier). Despite my reluctance to leave the dig at this early stage, it was clear that I had to go. Dr. Martill would take over as acting dig leader in my absence, and despite our joint expectation that everything would soon be finished, he gave me an undertaking that if some well-preserved and associated skull material started appearing, he would ensure that

it was left and not lifted until I had returned and seen it in place. But we were both wrong. When I returned three weeks later, bone was still being exposed, with little sign yet of anything that might be skull material, or an end to the bone material being revealed. The problem was not the usual one on digs, of difficulty in finding bone, but that 'too much' bone was being found – often diggers would complain about how they yearned for areas of clay devoid of bone, so that they knew that at least in one area they had come to an end of the preserved remains. The problems of excavating the material had grown over the days that I had been away. Contrary to appearances when the bed was first cleared, the topography of the clay layer did undulate slightly – and an incautious hand could accidentally go through bone, especially as some elongated rod-like components seemed to be long enough to lie proud of the soft clay layer that the bulk of the bone was held within, so that it projected into the harder slabs of the overlying bed. These topographical problems were compounded by a degree of faulting criss-crossing through the bed that had become apparent when the shell bed had been removed during early hand excavation. Although these faults did not appear to run directly through many bones, and the throw was not too significant (it was never too far from the broken end of one part of a bone to its matching broken surface in an opposing block), this still added complications which might again lead unwary excavators to accidentally excavate through bone. There was a core area of bone that ran in an area about 14 metres by 8, and within that there were many areas that were multi-layered, so that after one layer of bone had been exposed, mapped on to large plastic sheets and removed, another layer came to light. This was particularly problematic and time consuming in an area christened 'Green Bay' (named after the couple that dedicatedly excavated it, Peter and Margaret Green, of the Stamford Geological Society) that was densely filled with gill rakers, and ultimately this could only be resolved by removing roughly 7cm deep slabs of the area, in the hope of full excavation at a later date in laboratory facilities. Also problematic was the bone itself, which baffled seasoned excavators of Oxford Clay reptiles with over twenty years experience, who were entirely unprepared for a fossil animal with so many bones that were often so thin and delicate, yet sometimes exceptionally large and always incredibly fragile. This caused particular problems when trenching around some of the larger bones for plaster jacketing, as there would often be dozens of smaller bones lying around the perimeter, which could unwittingly be destroyed by the incautious digger. The clay needed to be pared away from the bones using dental tools - painstaking and time consuming, but the only way to safely release the bones from this matrix. Traditional methods of applying Paraloid B72 conservation glue had to be distinctly refined – although one could get away with applying thick mixes of this substance to reptile bone in the field, with this fossil fish, the glue simply obliterated the bone and made it extremely difficult to lift from the clay. And yet, in contrast, if the bone did not receive Paraloid B72 very soon after being exposed to the air, it would desiccate and start to break down within a couple of days. This was a particularly significant problem in the first few weeks of the dig when large areas of bone were being exposed faster than they could be protected, and the weather was fluctuating between intense heat and heavy downpours of rain, which alternately baked and flooded the site (see Figs. 23-25).

Although all of these factors were part of an elaborate learning curve for all involved, they also meant that, in conjunction with the quantity of bone being way in excess of what was predictable from existing material, they massively increased the amount of time that the dig took. The new specimen of *Leedsichthys* soon acquired the nickname of 'Ariston', because it simply went 'on and on' (as the old commercial advertisement used to declare). This unpredictability in terms of quantity of material meant that numbers of people available to dig dwindled when the largest amount of bone had to be lifted – after the 26th July, the core team dropped to just three individuals as dedicated diggers on the site. Eventually, the site had to be closed on Thursday 26th September, not because all the bone had been removed, but for two rather more pragmatic reasons. Firstly, the university term was about to commence, which mean that the diggers (both students and staff) needed to return to their various institutions. Secondly, the Hanson Brick Company needed the Portakabin back that they had kindly lent us over the summer in order that we could store the collected specimens in. Both of these factors meant that it was time for the site to be evacuated for that field season. A nine tonne truck was hired for the mammoth job of transporting all of the many hundreds of clay and plaster blocks into more long term storage (Fig. 26).

In August 2003, a small group of diggers reassembled at the Star Pit, to clear the rest of the bones from the exposed bed, for three reasons: firstly to ensure that there was no opportunity for individuals to plunder bones from the bed after the broadcast (planned for a month later) of a television programme reporting the exceptional find (Dawn, 2004); secondly to assess the degree to which bones were continuing into the cliff, and whether it was therefore worth removing more of the cliff in the hope of retrieving more of the same specimen; and thirdly to ensure that should it prove necessary to bring back a heavy digger to take the cliff back further, that there would be no danger that bones left in place on the excavation bed would be damaged by the digger returning. For two weeks, these individuals laboured to clear the remainder of the bone, supported by the Palaeontological Association and the National Museums of Scotland, within a small window of time formed by the availability of individuals to work without jeopardising their own summer project work. The work was made hard by the impact of winter weather, which had homogenised the upper strata, making it difficult to distinguish and separate them during excavation – the 'pen-knife' excavation beloved of the previous year was no longer possible. Following this, the onset of summer had reduced the surface layers to fine flakes of shale, which was difficult to remove cleanly. By the end, the site had been cleared to a degree satisfactory to the diggers, and plans were in place for removal of the cliff. It is planned that, depending on the availability of myself or Dr. Martill, the cliff

removal will not take place until the start of the next field season (2006) – partly so that further bones will be secured safe from potential private collectors within the cliff, and partly because the environmental protection of 20 metres of clay on top of a bed is invaluable: a fresh bed relatively unaffected by weather will be considerably easier to work than one which is exposed to the rigours of the Fens winter.

What have we learned from this remarkable fish specimen (registered with Peterborough City Museum as PETMG F174) – a discovery already described as the most important British vertebrate fossil find since the dinosaur *Baryonyx* was excavated in 1983? The specimen is exceptional in a number of important respects, including quantity of material (over 2,300 bones collected by the end of the 2003 field season, see Fig. 27), the presence of paired bones for the first time in a specimen of *Leedsichthys*, and remarkable clarity of skeletal growth structures on many of its bones, from gill-rakers to hyomandibulae and fin rays. Some of these growth structures superficially resemble growth rings, which hold out some promise of yielding growth data for this animal. With great optimism, Dr. Martill and myself had hoped for some sign of stomach contents as an indicator of diet: the fish has long been regarded as an edentulous suspension feeder like a baleen whale or a basking shark, in part because of its unusually large (over 7.5cm in length) gill-rakers in the absence of any teeth, but some preserved evidence from its gut would help to remove any ambiguity over this. It rapidly became clear that the component of the skeleton that had been preserved within the cliff would not contain this region of its body (that appears to have ended up as part of the aforementioned hypothetical Norfolk bathroom extension), but some small fish vertebrae were preserved within the central mass of gill rakers, which might serve as an indicator of some of the prey items that *Leedsichthys* (perhaps inadvertently) fed upon (see Fig. 28).

In addition to the retrieved remains themselves, and of equivalent importance, is the documentation – a detailed series of plastic mapping sheets (roughly 6 x 2 metres each – see Fig. 29), paper maps, field notes and a host of digital images, all of which make it possible to recreate the disposition of the bones as they were originally found.

Funding is currently being sought for the Herculean task of preparing the bone out of the clay slabs collected – an estimated task of one and a half person years in duration, to fully clean the more than 2,000 bones thus far collected. In the interim, Alan Dawn, the bone plasterer *par excellence* of Peterborough City Museum and Stamford Geological Society, has been working at cleaning occasional bones, but as a part-time volunteer it is slow and arduous work, at a rate of approximately a dozen every three months – a sign of both the scale of the problem, and the difficulty of the work (Fig. 30). Particularly problematic will be the preparation of the most fragile and complex structures, the pectoral fins (Fig. 31), currently embedded in robust plaster jackets and layers of B72 glue (Fig. 32).

It is clear that there is much more of Ariston's bony remains still in the Star Pit, and hopefully funding can also be raised to remove a little more of the cliff (which the skull remains seem to be heading into) and resume the dig armed with an informed and realistic schedule, and a full complement of diggers.

CONCLUDING REMARKS

Alfred Leeds remains a pioneering figure from the nineteenth century 'bone rush' of vertebrate palaeontology. As a single collector, the quality and quantity of his excavated material (in March 1894, just four years after selling his entire collection to the British Museum (Natural History), his newly formed collection was insured with the Insurance Company of North America for £1,000), and its worldwide distribution, is without peer. He personally found no difficulty in reconciling his theological beliefs with Science. Indeed, in a lecture he gave to local people at Glinton School one spring, he criticised 'religious instructors' for failing to keep up to date: "Religion must work with & keep up with science."

We sit at the start of the 21st century, and look back at how much we have learned in the last 150 years. Yet with all our increases in knowledge and understanding, it is humbling to realise how little we have moved forward: as lowly a vertebrate as a fish, whose fossil remains were first described well over a hundred years ago, is little better understood today than it was at the end of the nineteenth century; the recent rise in Christian Fundamentalism has forced creationism back into the school classrooms of the USA and Europe, through the supernatural doctrine of 'intelligent design' (Brumfiel, 2005; Gewin, 2005). A hundred years ago, Alfred Leeds described the cause of the problem as being that the "negligence of churches in not keeping up with [the] times [is the] cause of much unbelief [and] too much going back to the ignorant beliefs, forms, and superstitions of [the] middle ages." Although in many areas, hugely significant progress has been made since the Victorian era, in others, the progress seems a lot harder to discern.

ACKNOWLEDGEMENTS

Many people have helped in the progress of this project. Firstly, those individuals who have given access to key specimens in public collections: not only Alison Longbottom, Peter Forey and Sandra Chapman of the Natural History Museum (London), but also Ronald Böttcher (Stuttgart), Bettina Reichenbacher (München), Ronald Winkler and Ulf Linnemann (Dresden), Gunther Viohl (Eichstätt), Gloria Arratia & Hans-Peter Schultze (Humboldt Museum, Berlin), Lothar Schöllmann and Christina Reimann (Münster). Secondly, those that financed and supported the tour of collections abroad, and the transportation of specimens on loan – in particular the Blodwen Lloyd Binns Bequest Fund of the Glasgow Natural History Society, Jon Jeffery and Donna Saxby as well as Alison Brown.

The dig for Ariston itself had some direct financial benefactors, who have often gone unsung - palaeontological digs rely heavily on the enthusiasm and effort of volunteers, but this excavation was extremely fortunate in being financially supported by a number of bodies, primarily through the gratefully appreciated approaches of Dave Martill - without whom, the dig simply could not have happened. NERC's emergency funding route, and the Aggregate Levy's Sustainability Fund are particular contributors, but the major funder, helping both field seasons (in particular to cover the costs of hiring excavating machinery from R&R Plant Hire, with the highly skilled Dave Peppercorn), was the Palaeontological Association. Other contributors were English Nature, the Stamford Geological Society, the East Midlands Geological Society, and the Friends of Peterborough Museum. The owners of the Star Pit at Whittlesey – Hanson Brick – gave us fantastic hospitality and access to essential facilities as well as the permission to excavate Ariston, and Andy Mortlock was a stalwart point-of-contact. Further help in kind was in particular provided by the Hunterian Museum (University of Glasgow), the National Museums of Scotland and also by the University of Portsmouth - but the most significant contributor in this respect was all the diggers, who gave their time for no remuneration whatsoever - making a total of over 3,000 working hours in the pit over both field seasons. Special mention and thanks go to Tom Challands and Kay Hawkins in this regard. Sarah Earland, Peter and Margaret Green gave particular specialist expertise to the dig. Nick Watts and Adeline Ramage tried hard to make the filming as painless as possible, which was appreciated. Dave Martill has kindly allowed the reproduction of some of the images used in this article.
Special thanks to Julian and Louis Leeds for access to their family's archives, and Rosie Wyndham (née Leeds) for photograph sourcing. Susan Snell, Polly Tucker and Karen Taylor's help in guiding myself and Leslie Noé through the NHM's correspondence archive is gratefully acknowledged.
Finally, appreciation is expressed to John Wagner and Carlos Ezquerra for coming up with the 'Big Meg'.

INSTITUTIONAL ABBREVIATIONS

GLAHM = Hunterian Museum, The University of Glasgow, Scotland.
SMN ST = Staatliches Museum für Naturkunde in Stuttgart, Germany.
BMNH = Natural History Museum (London), England.
PETMG = Peterborough Museum and Art Gallery, Cambridgeshire, England.
CAMSM = Sedgwick Museum of Geology, Department of Earth Sciences, University of Cambridge, England.

REFERENCES

Blackmore, V. & Page, A. 1989. *Evolution The Great Debate*. Lion Publishing plc, Oxford.

Brumfiel, G. 2005. Who has designs on your students' minds? *Nature*, **434**, 1062-1065.

Chambers, R. 1845. *Vestiges of the Natural History of Creation*. John Churchill, London.

Crathorne, N. 1973. *Tennant's Stalk: The Story of the Tennants of the Glen*. Macmillan, London.

Darwin, C. 1859. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. John Murray, London.

Dawn, A. 2002. The Year of the Fish *Leedsichthys problematicus*. *Musings* [33], 1-2. 1-12-2002. Peterborough, Friends of Peterborough Museum and Art Gallery.

Dawn, A. 2004. *Leedsichthys problematicus*. *Geology Today*, **20**, 53-55.

Gewin, V. 2005. Scientists attack Bush over intelligent design. *Nature*, **436**, 761-761.

Hillier, R. 1981. *Clay That Burns: A History of the Fletton Brick Industry*. London Brick Company Limited, London.

Hudson, J.D. & Martill, D.M. 1994. The Peterborough Member (Callovian, Middle Jurassic) of the Oxford Clay Formation at Peterborough, UK. *Journal of the Geological Society*, **151**, 113-124.

Huene, F.V. 1901. Notizen aus dem Woodwardian-Museum in Cambridge. *Centralblatt für Mineralogie, Geologie und Paläontologie*, **1901**, 715-719.

Lamarck, J. B. P. A. de M. 1809. *Philosophie Zoologique ou Exposition des Considerations relatives a l'Histoire Naturelle des Animaux*. Chez Dentu, Paris.

Leeds, A.N. Letter from Alfred Nicholson Leeds to Arthur Smith Woodward. Woodward, A. S. 18-3-1898.

Leeds, A.N. Letter from Alfred Nicholson Leeds to Arthur Smith Woodward. Woodward, A. S. 28-2-1913.

Leeds A.N. & Woodward, A.S. 1897. Report on a Field-trip to Peterborough. *Proceedings of the Geological Association*, **15**, 190-192.

Leeds, E.T. 1956. *The Leeds Collection of Fossil Reptiles*. Oxford.

Liston, J. J. 2000. *Archaeopteryx* and the evolution of feathered flight: the hidden story. *Quarterly Journal of the Dinosaur Society*, **4 (1)**, 6-14.

Liston, J.J. 1999. Dicynodonts, brick-pits, and hunting for that first dinosaur: the Mesozoic vertebrates in the museums of Scotland. *Dinosaur World* **6**, 55-57.

Liston, J.J. 2004. An overview of the pachycormiform *Leedsichthys*. In: *Mesozoic Fishes 3 - Systematics, Paleoenvironments and Biodiversity*. (Ed. by G. Arratia & A. Tintori), pp. 379-390. Verlag Dr. Friedrich Pfeil, München.

Liston, J.J. & Noè, L.F. 2004. The tail of the Jurassic fish *Leedsichthys problematicus* (Osteichthyes: Actinopterygii) collected by Alfred Nicholson Leeds - an example of the importance of historical records in palaeontology. *Archives of Natural History*, **31**, 236-252.

Liston, J. J. & Sanders, H. L. 2005. The 'other' Glasgow Boys: the rise and fall of a school of palaeobotany. In: *History of Palaeobotany: Selected Essays*. (Ed. by A. J. Bowden, C. V. Burek, & R. Wilding), pp. 197-228. Geological Society, London.

Longwell, C.R. 1933. Memorial tribute to John Walter Gregory. *Bulletin of the Geological Society of America*, **44**, 414-415.

Martill, D.M. 2002. A Very Big Fish. *Planet Earth* , 4-7.

Martill, D.M. 1986. The world's largest fish. *Geology Today*, March-April, 61-63.
Martill, D.M. & Liston, J. J. 2003. Big Gamble for a Big Dead Fish. *The Palaeontological Association Newsletter*. [52], 40-43.
Michelis I., Martin Sander P., Metzdorf R. & Breitkreuz, H. 1996. Die vertebratenfauna des Calloviums (Mittlerer Jura) aus dem Steinbruch Störmer (Wallücke, Wiehengebirge). [The Callovian (Middle Jurassic) vertebrate fauna of the Störmer Quarry (Wallücke, Wiehengebirge).]. *Geologie und Paläontologie in Westfalen*, **44**, 5-66.
Probst E. & Windolf, R. 1993. *Dinosaurier in Deutschland*. Bertelsmann, München.
Rolfe, W. D. I. 1985. William and John Hunter: breaking the Great Chain of Being. In: *William Hunter and the Eighteenth Century Medical World*. (Ed. by W. F. Bynum & R. Porter), pp. 297-319. Cambridge University Press, Cambridge.
Thomson, K. S. 2000. Huxley, Wilberforce and the Oxford Museum. *American Scientist* **88**: 210-212.
Woodward, A.S. 1889a. Notes on some new and little-known British Jurassic Fishes. *Annals and Magazine of Natural History*, **Series 6, Volume 4**, 405-407.
Woodward, A.S. 1889b. Preliminary notes on some new and little-known British Jurassic fishes. *Geological Magazine*, **Decade III Volume 6**, 448-455.
Woodward, A. S. 1890. Notes on some new and little-known British Jurassic fishes. Report of the fifty-ninth meeting of the British Association for the Advancement of Science. 585-586. John Murray, London.
Woodward, A.S. 1916. On a new specimen of the Liassic pachycormid fish *Saurostomus esocinus*, Agassiz. *Geological Magazine*, **Decade VI Volume 3**, 49-51.
Woodward, A.S. 1917. Alfred Nicholson Leeds, F.G.S. *Geological Magazine*, **Decade VI Volume 4**, 478-480.

PLATES AND FIGURES

PLATE 1.

FIGURE 1. Number 11, Grosvenor Terrace, in Glasgow's West End, around the time when Mary's family lived there, at the end of the nineteenth century. The house was only a few minutes walk away from the University of Glasgow's Hunterian Museum. Photograph used by courtesy of the Mitchell Library, Cultural & Leisure Services, Glasgow City Council.

FIGURE 2. Alfred Nicholson Leeds and Mary Ferrier Fergusson, together in a Peterborough photographic studio, around 1875. Image courtesy of Julian Leeds. Copyright resides with the Leeds Family.

FIGURE 3. The Leeds family home at Eyebury. Image courtesy of Julian Leeds, from the unpublished manuscript 'Eyebury and the Leeds collection', 1938/9.

FIGURE 4. The tail (BMNH P.10,000) of *Leedsichthys problematicus*, as displayed in 1937 (NHM-ESL negative number 1660). The span of the tail is 2.74 metres. Thurlow Leeds recalled why it took some nine months to reassemble the "thousands of pieces" of the tail collected: "a packet of fragments representing a length of 3 or 4 inches, and belonging possibly to two original rays, contained on the average (in the slenderer parts) 120 fragments" (Leeds, 1956). By permission of the Trustees of The Natural History Museum (London).

FIGURE 5. Professor John Walter Gregory, Chair of Geology (1904-1929) in the University of Glasgow, and Honorary Curator in Geology for the Hunterian Museum. Photograph © Hunterian Museum, University of Glasgow.

FIGURE 6. Dr. William Robert Smellie, Assistant Curator in Geology, circa 1915. He worked extensively on reconstructing the marine reptiles of Alfred Leeds bought for the Hunterian Museum. Reproduced with kind permission of Valerie Boa, with whom copyright resides.

FIGURE 7. The mounted skeleton of *Ophthalmosaurus icenicus* (GLAHM V1070), as displayed in the Hunterian Museum from about 1916-1966. Picture probably taken between 1916 and 1920 by S. Finland. Photograph © Hunterian Museum, University of Glasgow.

FIGURE 8. The full extent of 'Big Meg' (specimen GLAHM V3363), laid out in a corridor of the Hunterian's main research store. John Faithfull (1.8m) is included for scale.

FIGURE 9. The bone sketched by Alfred Nicholson Leeds in his letter to Arthur Smith Woodward. It is a component of specimen GLAHM V3363 ('Big Meg'). Bone is a 77cm long preopercle.

FIGURE 10. Extract from a February 1913 letter from Alfred Nicholson Leeds to Arthur Smith Woodward, enquiring about a bone of *Leedsichthys* that he had found. (NHM-GL DF100/55/468). By permission of the Trustees of The Natural History Museum (London). Copyright resides with the Leeds Family.

PLATE 2

FIGURE 11. *Saurostomus esocinus* (BMNH P11126), 1.3 metres long.

FIGURE 12. Detail from the skull of BMNH P11126 (field of view is 11cm wide).

FIGURE 13. Skull of SMN ST 52472, clearly showing outline of maxillary.

FIGURE 14. Skull of SMN ST 50736, clearly showing outline of dentary.

FIGURE 15. Maxillary of 'Big Meg' (GLAHM V3363).

FIGURE 16. Dentary of 'Big Meg' (GLAHM V3363).

FIGURE 17. The first bone of 'Ariston' (PETMG F174) – sent for identification after excavation from the Star Pit in 2001. Below is a piece of *Leedsichthys* identified by Friedrich Von Huene in 1901 as a stegosaurian tail-spine (CAMSM J.46873).

FIGURE 18. The *Leedsichthys* locality in the Star Pit. Alan Dawn and David Martill stand next to the quarry face, indicating the 8.5 metre distance over which bone was found on 22nd October 2001. David Martill (right) is pointing at the horizontal bed that the bone was emerging from. A yellow 'X' between them marks where the first bone sample was retrieved from the bed by Marcus Wood.

FIGURE 19. The Komatsu excavator, driven by Dave Peppercorn, obliterating the 20 metre high cliff sitting on top of the fish. © D. M. Martill.

PLATE 3.

FIGURE 20. The author views the newly exposed bed, prior to manual excavation commencing, on 29th June 2002. © D. M. Martill.

FIGURE 21. First excavated area, showing slippage 'fault' to left. Margaret Green for scale. © D. M. Martill.

FIGURE 22. Reconstruction of *Leedsichthys* as an 18 metre fish by Bob Nicholls (September 2003), with line to show the portion of the body (to the left) thought to be contained within the cliff. © Bob Nicholls, Palaeocreations (www.paleocreations.com).

FIGURE 23–25. The site regularly flooded (23) and required to be pumped out (24) before excavation could continue (25).

FIGURE 26. Fish-van: the nine tonne truck filled with plaster jackets eontaining the bones of the fish. In the foreground is a Channel 4 filmcrew.

PLATE 4.

FIGURE 27. Peter Green's map of the site: each cross marks the corner of a 1 metre square grid, designed and constructed by him, that was utterly invaluable for accurately recording the site. For simplicity at this scale, only the largest components have been included. © Peter Green, 2002.

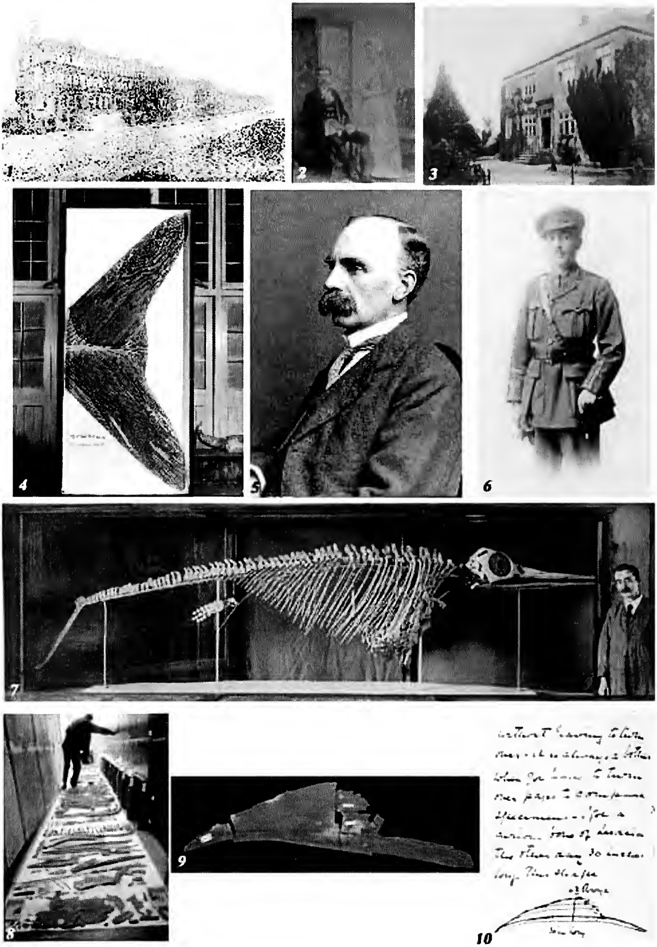
FIGURE 28. Sketch by Bob Nicholls (August 2004) to indicate the indiscriminate ingestion of an extremely large suspension-feeding Jurassic fish. © Bob Nicholls, Palaeocreations (www.paleoereations.eom).

FIGURE 29. Unrolling one of the 18 plastic mapping sheets created to map the finds during the two field seasons. Peter Green (orange hard hat) directs operations. © D. M. Martill.

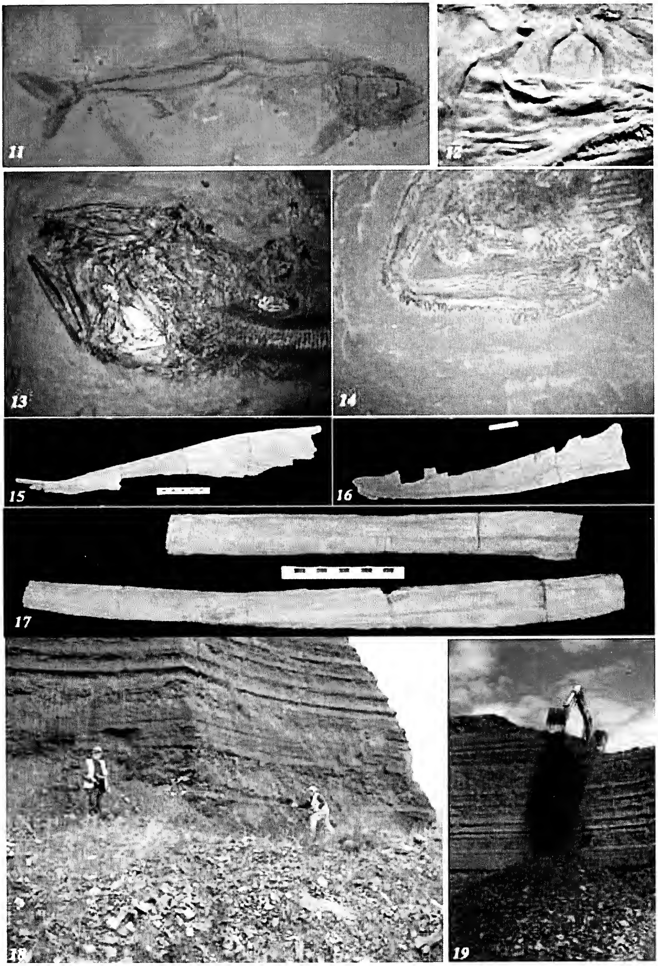
FIGURE 30. A handful of the more than 2,300 bones retrieved from the Star Pit site. These have been prepared out of their clay matrix by Alan Dawn, of the Peterborough City Museum.

FIGURE 31. The right pectoral fin of Ariston (PETMG F174/10,002), pedestalled prior to being jacketed in plaster for removal. © D. M. Martill.

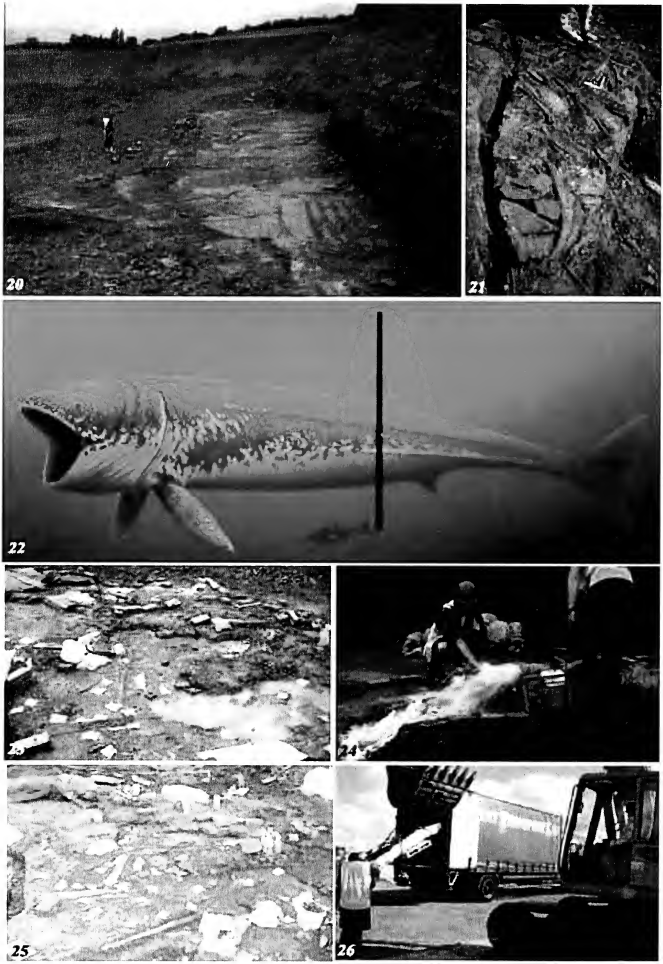
FIGURE 32. The left pectoral fin (with overlying dermal bones, PETMG F174/10,025) hoisted into the air on the last day of the first field season. © D. M. Martill.



Liston. Plate 1.

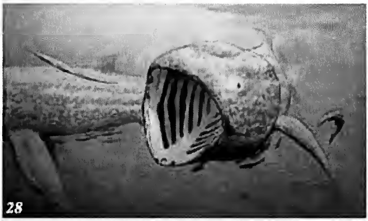


Liston. Plate 2.



Liston. Plate 3.

27



28

29

30

31

32

Liston Plate 4.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 73-75.

DYER'S GREENWEED ON THE M74 MOTORWAY EMBANKMENT IN LANARKSHIRE (VC 77)

P Macpherson[1] & JR Hawell[2]
15 Lubnaig Road, Glasgow G43 2RY[1]
40 Durban Avenue, East Kilbride G75 9PA[2]

INTRODUCTION

While travelling south on the M74 on 1st July 2004, one of the authors (JRH) noted small clumps of Dyer's Greenweed (*Genista tinctoria*) on the grassy embankment of the southbound carriageway, between Junctions 12 & 13. Returning on 13th July he noted two patches on the northbound embankment approximately three miles south of J 12. The following day he walked across moorland adjacent to the M74 until he reached the most extensive patch on the southbound embankment, where the plant covered an area of approximately three square metres. It was close to the boundary fence, thereby facilitating the attainment of an accurate GPS reading (NS88574: 27340), photography (Fig. 1) and the collection of a specimen.

RECORDS

Both authors travelled along the appropriate stretch of the M74 on 15th July and attempted to count the colonies. In such a situation (at speed), the plant is most likely to be confused with the much more common Lady's Bedstraw, but is more compact and of a deeper yellow.

We easily re-located the Dyer's Greenweed at the GPS site above and obtained a formal voucher specimen from a colony further south at NS91266: 26531, which is immediately south of the police motorway observation point. A further small patch was noted within a mile of the J13 exit.

The first plant noted while travelling north was in the vicinity of the Birkshaw Burn, the second just south of where power cables cross the motorway and a third approximately 100 metres before reaching the motorway sign indicating that the J12 exit is one mile ahead.

In order to obtain accurate locations for the plants previously observed on the northbound carriageway embankment, JRH walked down the field edges. The most northerly known site in Lanarkshire is on the embankment at NS86435: 30442. The other two locations were at NS86887: 29170 and NS87457: 28389.

BRITISH DISTRIBUTION

Dyer's Greenwood has been described as a small deciduous shrub of rough pastures, old meadows, grassy heaths, cliffs, road verges and field edges on heavy soils, usually calcareous to slightly acidic clays. It is considered to have declined considerably since the 1940s (Pearman 2002). The post-1970 British distribution on a vice-county basis has been given in the *Vice-County Census Catalogue* (Stace *et al* 2003). Native records are given for Dumfriesshire (VC 72), Kirkcudbrightshire (VC 73), Wigtownshire (VC 74), Berwickshire (VC 81) and, strangely, Easter Ross (VC 106). West Lothian (VC 84) is listed in the alien category.

The British distribution is given on a hectad basis on a map in *The New Atlas of the British and Irish Flora* (Preston *et al* 2002) (Fig.2). The records conform with those listed above, but do not include an Easter Ross entry.

INTRODUCTION TO SITE

With regard to the method of introduction of the plant in Lanarkshire, the possibilities are that it has merely been a natural extension of its range on to a suitable habitat when the embankment was created or that it was included accidentally in the seed-mix used to vegetate the embankment.

These questions were posed when a specimen was exhibited at the 2004 autumn meeting of the Glasgow Natural History Society. The two members who voted did so in favour of the seed-mix. The only person voting at a subsequent meeting of the Botanical Society of the British Isles believed it to be a natural extension.

We have since learned that Dyer's Greenweed was not (at least intentionally) included in the seed-mix used on these banks. Further, there were no neighbouring plants such as one associates with seed-mix in the vicinity.

During 2005 we again travelled on the relevant part of the motorway on a number of occasions and consider that the number of colonies has remained unchanged.

In the coming seasons we hope to search the surrounding area for possible source plants. If it has seeded naturally, then it may be classified as a native occurrence (Macpherson *et al* 1996).

ACKNOWLEDGEMENT

We are grateful to David Welch for obtaining information regarding the grass seed and to the authors for permission to reproduce the map from the *New Atlas of the British and Irish Flora*.

REFERENCES

Macpherson, P, Dickson, JH, Ellis, RG, Kent, DH & Stace, CA (1996). Plant Status Nomenclature. *BSBI News* 72, 13-16.

Pearman, DA (2002) New Atlas 10km Census Dataset Details; *Genista tinctoria*, in Preston, CD, Pearman, DA & Dines, TD (2002). *New Atlas of the British and Irish Flora.* Oxford University Press, Oxford.

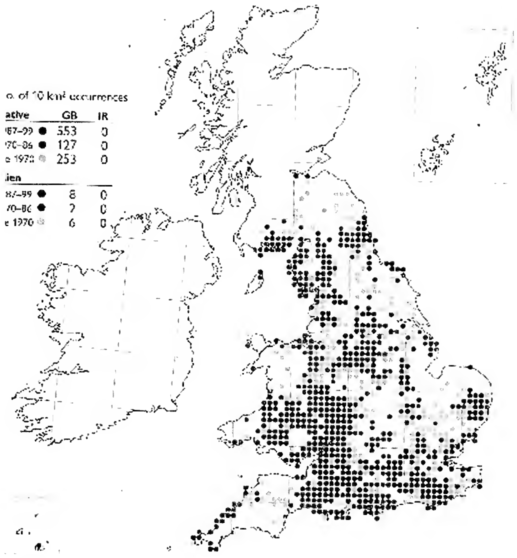
Preston, CD, Pearman, DA & Dines, TD (2002). *New Atlas of the British and Irish Flora.* Oxford University Press, Oxford.

Stace, CA, Ellis, RG, Kent, DH & McCosh, DJ (2003). *Vice-County Census Catalogue of the Vascular Plants of Great Britain*, Botanical Society of the British Isles, London.

Figure 1. Dyer's Greenweed (*Genista tinctoria*) on the grassy embankment of the southbound carriageway of the M74, between Junctions 12 & 13.

Figure 2. British distribution of *Genista tinctora*, Dyer's Greenweed, given on a hectad basis on a map in *The New Atlas of the British and Irish Flora* (Preston *et al* 2002).

Genista tinctoria Dyer's Greenweed



Glasgow Naturalist 2006. Volume 24. Part 4. Pages 77-81 .

CLEANING THE CLYDE - A FIFTY YEAR FISHERIES REVOLUTION.

Howard McCrindle.
University Marine Biological Station,
Millport,
Isle of Cumbrae,
Firth of Clyde, Scotland KA28 OEG

Email: <Howardmccrindle@aol.com>

ABSTRACT
This paper documents the dramatic changes in the marine fisheries in the Firth of Clyde and surrounding areas from the 1950's to the present day. The author, who has had detailed professional experience of the fisheries during the whole of this period, describes the fishing season in the 1950's, and the change from the use of pairs of boats, the ring netters, bottom trawling, and mid-water trawling. The paper outlines the changes in fishing and species caught, from herring, and then queen scallops and scampi, to cod shaithe and hake. The introduction of advance echo sounders and net monitors, and the invasion by French and Spanish fishing vessels also receives comment.

THE 1950's FIRTH OF CLYDE FISHERIES

Ring netters

In the late 1950's the Firth of Clyde was fished predominantly for herring. A hundred ring netters chased the Silver Darlings. These beautiful boats were around fifty feet long and could carry roughly 20 tons each. They were powered by small diesels, mostly between 90 and 110 horsepower. The ring net didn't need a massive amount of power to make it work. The boats worked in pairs. When a boat located herring, the skipper made a "Ring" around the shoal, laying the large net in a semi circle. The "neighbour" boat picked up the end of the net and the two boats towed it into shape around the herring. The boats came together and the crew of the boat towing the end, jumped aboard the "shot" boat, to aid the other crew with the hauling, as the massive net could measure a thousand feet long and one hundred and fifty feet deep. The men hauled the netting by hand while the bottom of the net was pulled up by a small winch. When the bottom of the net was up aboard the boat, the herring were trapped in an enormous purse. It was a "kind" method of fishing. If the fish were found to be too small, they could be released without being damaged too much. Totally different to modern day trawls which indiscriminately hoover up everything in their path.

Even locating the herring was totally different in those days. Echo sounders were pretty primitive compared to the wonderful machines available nowadays.

In the summertime every boat had someone up in the bows, peering over the side. These skilled men could pick out shoals of herring in "the burning" the name given to the phenomenon caused by the phosphorescence given off by the plankton. They more than the skipper were in charge of deciding when to shoot the net.

At the spawny season on the famous Ballantrae banks, the herring were so close to the bottom that they couldn't be seen properly on the sounders. A lead weight was trailed along behind the vessel on a length of piano wire. The men "felt" the herring hitting the wire, and were even expert at telling where the ground was suitable to lay the net safely, just by trailing the weight along it.

Birds were used to find the fish as well. An "appearance," of herring , could be given by a flock of noisy gulls. Many a herring owes his demise to these birds, who could sense the fish even sixty or seventy metres below the surface. Gannets were studied too, and, even in the sixties I've seen five hundred baskets of herring and mackerel captured by ringing round a striking gannet, with no other sign to give away the fishes' presence.

The fishing season

The season started in the middle of June around the Summer Solstice, when the herring had " made up" after spawning in the spring. "The turn of the day" marked the time when the fat content in the herring was high enough to make the fish an outstanding meal, and Loch Fyne herring were sought after as the prime example of Scottish herring.

The Clyde Fleet

The Clyde fleet consisting of boats from Girvan, Maidens, and Dunure on the Ayrshire coast, along with boats from the west highland havens of Campbeltown, Carradale and Tarbert, fished locally in the Clyde all summer with some pairs foraging down to the Isle of Man in August. Virtually the whole fleet would take the long hike North about the time of Hallowe'en to fish the herring around the outer Hebrides, running their cargoes to either Oban or Mallaig. This fishery lasted till Christmas or shortly after, when the Clyde men returned home to follow the "spawny" herring as they made their way South to the spawning grounds on the famous Ballantrae banks, or on the gravelly shallows at the South end of Arran at the Brown Head.

When the herring had spawned, the fleet either went back to the North to fish recovering spent herring there, or tied up to "clean" the boats. The beautiful varnished hulls were scraped back to the bare wood before being re-covered in seven coats of varnish, a task that could take six or seven weeks. There was no other real option for the men at this time, as even the white fish were skinny after spawning and not really worth much.

This time of cleaning the boats finished the annual cycle and the pristine fleet would venture back out to hunt the Silver Darlings around the turn of the day again.

Apart from the herring fleet, there were a few small seine netters who were allowed to fish inside the three mile limit. In Ayrshire these boats, which had to be under forty feet in length were known as Bumfies, a word derived from "bum flies", the kind you'd find flying round the back end of a cow or horse and indicative of their lack of size. There were Bumfies in all the Clyde ports from Tarbert, Rothesay, Carradale, Campbeltown, Dunure, Maidens, Ayr , Ballantrae and Stranraer. Their catch would consist of haddock, cod, whiting, hake, plaice, skate and various other species. These little boats did quite well and as they were seine netting they could only work on reasonably clean ground. This meant that the rocky patches, most numerous close inshore, were never touched and were a safe haven for fish.

Outside three miles most of the time there were a few larger seine –netters working mostly from Ayr, and skippered by former East coast men who had moved to the West coast. This fleet of seiners grew tremendously in the spring months and a fleet of East coast boats from the Moray Firth and the Firth of Forth came West to chase the cod, whiting and haddock as they gathered on the spawning grounds along the Ayrshire, Arran and Kintyre coasts. I have seen the seiners filling Ayr harbour from side to side in the early sixties when I was a boy out on holiday with my father, perhaps fifty or so boats, all targeting fish ready to spawn.

This fleet was augmented by quite a few of the ringers from the Ayrshire ports after the Ballantrae Banks fishing was finished

The sad thing about this was that these fish had come from all over to lay their eggs, and just before they had the chance to do so, they were plucked from the sea and the precious roe, meant to carry on the stock, was boiled, sliced, coated in flour, fried and eaten. They were totally delicious , but thinking back it was insanity . Although it is now easy to see the mistakes made, in those days, this was perhaps the only time that these fish were seen by the Clyde boats. It was definitely the time when large numbers of fish congregated together and enormous hauls could be made. That's what the fishermen were there for, they had families to feed, rents and mortgages to pay, boats to maintain. If anyone thinks they had an easy time, I can tell them that the laziest fisherman I ever knew, worked twice as hard as any man I met working ashore perhaps with the exception of some farmers.

This was the Firth of Clyde, in the late fifties. There were other boats in the Clyde as well in the late summer, when the hake spawned to the west of Ailsa Craig. These fish were not as popular as they are today but in the fifties and sixties, they attracted the large seiners from the East coast, and again were caught in large numbers just before they spawned. The only time the bulk of the Clyde fleet nibbled at the stock, was in the deep trench to the east and north of Arran when the herring were "spent" and unfit to catch. This was done illegally, with the fishery cruiser interrupting the operations on a regular basis.

French and Spanish boats

Until then, the only legal trawling done in the Firth was by Frenchmen and Spaniards. Although it seems ridiculous now, the French and Spanish could trawl in the area where we could not. What a farce! They were allowed to work outside the three-mile limit, but I remember one boat leaving Maidens harbour to go scallop dredging in Culzean bay with the tide early one morning. The scallops were fished by a few boats on a seasonal basis. This fellow was steaming northwards when he nearly collided with a French trawler towing half a mile from the shore. This boat was in total darkness, not a light to be seen, and with the knowledge I now have, he would have been towing for the high value flatfish species of Dover Sole, Brill And Turbot. Thinking back and realising how plentiful the fish were, these French fishers must have made a fortune, and their knowledge of the grounds was such that they could tow from the Isle of Man, all the way into the Clyde. There are damn few Scotsmen who could do this yet, 40 odd years later.

The biggest change – joining the Irish Register

The biggest change was to come when a few of the Clyde boats went south to fish Dublin Bay prawns from the Irish port of Howth. Around this time a few of the local boats sailed south to work the ring net at the famous fishery around the southern Irish port of Dunmore East in Co Waterford. To participate in this fishery the boats had to join the Irish register and six boats from Maidens and Girvan were to be seen with the letters C for Cork or D for Dublin on their shoulders and quarters. These boats made fortunes down at Dunmore, the men bringing suitcases of money back with them at the end of the season.

THE 1960's FISHERIES

The influx of trawlers – scampi and cod

Moving forward into the "Sixties" the Clyde fishery changed dramatically. The boats began to concentrate more on trawling due to various factors. Scampi, the product made from the prawn meat, was becoming ever more popular. The price started to rise accordingly. The result of which made the job more viable. Soon most of the boats spent half the year at the trawl. The other half of the year was spent in the Minch for the winter and at the Ballantrae Banks in the spring.

The boats started to trawl for cod after the Banks fishing ended, and less and less of them bothered to try the seine net, mainly because trawling was less labour intensive. By the mid sixties, a lot of the boats were less inclined to go to the herring at all, and by the end of the sixties most of the fleet were virtually full time trawlers.

As the men became more proficient with the trawl, they started to diversify, and a few of the Ayrshire boats began to work on the more rocky inshore grounds using "Bobbins", large rubber wheels which came along in

front of the bottom rope of the net, bouncing over the boulders and allowing the net to take fish which previously were inaccessible to the "clean ground" nets, used to catch the prawns and fish on the muddier parts of the firth.

Queen Scallops

As the men expanded their knowledge of the previously virgin grounds, it was soon obvious that there were tons and tons of queen scallops, or queenies, as they were known, all over the firth. In 1967 or 68, we started to sell a by catch of these queenies to a factory in Eyemouth for six shillings (30p) per stone. As you could catch a ton by accident for an hour or less, the fleet soon realised there was a substantial fishery to be developed. In the next few years most of the Kintyre fleet spent the months of August and September at the queenies. A few of the Ayrshire boats were at them too but never to the same degree. The queenie nets were tiny, heavy twined nets rigged to bobbins and though they were not indestructible, they could take a lot of punishment. The nets were joined straight on to the trawl doors. This meant they could travel in places where the fish bobbin nets, which had sometimes ninety feet of sweeps (combination wire rope) between them and the doors, could not. Although the little nets were inefficient for catching fish, they did catch some, and invariably, these were fish which would never have been touched in the past. Add that fact to the number of boats at the fishery, and it becomes a substantial amount of fish, thousands of boxes, I 'm pretty sure.

Introduction of the mid-water trawl

While all this development was going on at the whitefish, prawns and queenies, an even bigger transformation was taking place at the herring fishing.

The mid-water pair trawl arrived in the Clyde. Some of the ringers had dabbled at the job , but none had taken it on as their main way of fishing,. Most of the trials they had carried out were in the Minch or at the Isle of Man. In the spring of 1968 two pairs of boats from Girvan and Maidens sailed with only the pair trawl aboard. There were around a dozen larger boats from Peterhead and Fraserburgh in the north east and from Kilkeel in northern Ireland fishing in the Clyde that year and a pair of ex ringers from the Firth of Forth. These boats fished extremely well and it was only a matter of time before the local men were forced to upgrade first their engines, to have the necessary power to do the job, then their boats, to be really efficient at it.

The biggest difference was that when the herring were scattered out, the ring net was ineffective. The ring net came into its own when the herring were in large shoals. If they were not, it was impossible to catch sufficient quantity in the area a ring net covered. The trawl on the other hand could be pulled along between the two boats for hours, gathering fish as they went. The result was that the trawlers were catching as much as two hundred baskets for three hours, while the ringers could not get a shoal thick enough to ring on.

Saithe

I was aboard one of the boats that were out as "pure" trawlers, and one night we caught a hundred and twenty boxes of saithe by accident. This was to prove of vital importance to me in the following years. The trawler crews did not need the same level of expertise as the ring netters. It was possible to go for a sleep while the net was being dragged along, working watches. This too was a factor, as you could not relax for a minute when ringing, as the gear had to be shot immediately the herring were located. The ring net men were on stand by from dark till daylight, a long time in the Scottish winter.

The net monitor

Another major factor in improving efficiency was the advent of the net monitor, a wonderful piece of electronic wizardry that was attached to the top of the trawl and enabled the skipper to see at a glance what depth his net was at, see the fish going into, over or under the net, allowing him to fine tune the gear to take the heaviest part of the shoal, a marvellous step forward.

Gradually the ring net disappeared, although a few Argyll boats stayed at it, and a handful of Ayrshire pairs worked in the Minch, into the seventies, doing really well but working in appalling weather.

THE 1970's FISHERIES

Saithe and Hake. Cod and Whiting.

Thus the Clyde herring fishery changed, but more was to come on the white fish front. On 4th of February, 1971, my 21st birthday, I went pair trawling for what I thought were thick shoals of herring south west of Pladda island at the south end of Arran. A tow through one of the short but dense marks on the echo sounder yielded thirty boxes of enormous saithe for fifteen minutes. This tow led to a massive amount of saithe being slaughtered in the following month as everyone and his neighbour joined in, boats from everywhere you could think of were participating in the extermination of thousand of boxes of these large pregnant fish. No one knew they were there in those numbers, and because they were up off the bottom, no one could have caught them if they didn't have the midwater trawl.

After this some of the pairs who didn't fancy prawn fishing, went into the deep water further north off Arran and trawled in pairs for the large hake. Some pairs made a reasonable living at this and a few pairs were at it for a month or two.

The next few years there was a large fishery for saithe in Kilbrannan Sound. From September to November, the saithe were slaughtered, lying night after night in the same place, gorging themselves on the dense clouds of copepods, or shrump, as the Argyll men called them, with a large fleet of boats from all over the Clyde and Northern Ireland taking thousands of boxes again.

Midwater trawling was not the only enemy the saithe had. As the fleet developed with larger boats and engines, the bottom trawls became bigger, and were pulled along faster. This increased efficiency led to large numbers of saithe being caught by the bottom trawl fleet as well at spawning time, south of Ailsa Craig especially. Cod and whiting were taken in huge numbers as well. I remember one evening in Girvan there were ten lorries loaded to go to the market in Ayr, around 2000 boxes! It seemed like there was an endless supply of fish at this time.
Around this time, the echo sounder was upgraded. Instead of reading a piece of paper to see the fish, a new colour video sounder was invented. It could work on two different frequencies at once and now it was possible to see each individual white fish, all the way down to the deepest water in the area, 600 feet. This was a wonderful invention for the skipper, but another nail in the coffin for the fish stocks.

Size difference between bottom caught and mid-water caught fish.

The fishing continued through the early seventies like this. The saithe started to become scarcer, as did the cod. A small hard core of modern boats were pair trawling for white fish most of the winter and into the spring in the deeper waters on each side of Arran and up into lower Loch Fyne. The most noticeable thing about this method was the size of the fish being caught. With a bottom trawl you were only catching the fish in the bottom three or four feet off the ground. With the midwater trawl however, you were bringing up cod as large as 60 pounds, haddock of 30 pounds, hake up to 30 as well,. It was very unusual to see fish of this size in a bottom trawl. This proved to us that cod was not a true demersal or bottom feeding fish, but spent most of their lives up in the midwater, especially when they were older.

Effects of the abolition of the three mile limit.

The of the most important factors in the demise of the Clyde fishery was the abolition of the three mile limit in the late 70's. After two or three years in which the authorities had taken a softly softly approach, the limit, which had greatly restricted fishing in the Firth, was done away with completely, giving the fleet total access to areas previously fished only when the fishery cruiser was out of the way.
While I don't believe that the boats fishing for prawns made a lot of difference to the fin fish stocks by going inside the limit, the boats targeting fish had complete freedom to get at the stocks close inshore, a luxury previously denied to them .

THE 1980's FISHERIES

Single boats using the mid-water trawl – Hydrofoil trawl doors.

In 1979 I experimented with a midwater trawl but without a neighbour boat to pull it with. The net was kept open by Hydrofoil trawl doors that went outwards when you towed them but upwards as opposed to downwards in the case of the bottom trawl doors. This method proved extremely efficient when I got it perfected and within a year the whitefish pair trawl was extinct. At Christmas 1979 there were two of us at the single boat pelagic trawl. After New Year there were 23 boats trawling up and down the Arran trench, that's the impact we'd made.

Cod, Hake, Whiting

Not all of these boats persevered at the job, but a good number of the Ayrshire men made it their mainstay for the winter months. Some of us went up the Clyde itself , working in the sheltered waters of Loch Long and from the Cloch down past Dunoon and Largs, and down the deep trench between Cumbrae and Bute. All of these areas yielded lots of cod, hake and whiting with a smattering of saithe and Pollack. No one had any idea these fish had been there, as they very seldom were seen in the bottom trawls. I remember one day in Loch Long we caught 90 boxes of mixed white fish. The five bottom trawlers beside us didn't have a box among them. This gives one an idea of the deadly efficiency of the method. I started to realise that I'd spawned a monster and it was getting out of control.
Eventually the boats made their way down to the North Channel, the turbulent stretch of water separating Scotland and Northern Ireland. This area suited the Pelagic trawl perfectly. Lots of deep water and a large population of hake and cod. There were some unbelievable catches of these large pregnant hake that first summer. 100 boxes for a day wasn't really unusual, with a good bye catch of other species. A large fleet of Irish boats from the ports of Portavogie and Kilkeel took up the job and added to the decimation. I've never seen the records of the landings made, but it must have been astronomical.
This carried on for a few years, some of the Irish boats, being larger and more powerful than ours, stayed at the job full time, and made fortunes.

THE 1990's AND AFTER

The decline of the fisheries

Eventually, it started to dry up, and by the late eighties, the writing was on the wall. We'd done it. Cleaned it out. This was impossible to imagine in the early days. It proved that these large fish, which had been virtually untouched since time began, had been supplying the eggs that continued the stocks. Now the smaller fish which were left were unable to produce enough young to keep the stocks strong.
Where we used to see these beautiful fish there are now only a few tiddlers, and even these vanish when they get to a certain size. Fishermen have proved over the years that they are adaptable to nearly anything, and really good at developing and refining fishing methods, till they are super efficient, too efficient, and sadly myself, I can't ever see the stocks recovering to anything like what they were.

With the evolution of wonderful fish finders, net monitors and trawl control systems, nothing that swims is safe. As we were doing it we thought we were making a better life for ourselves, while all the time we were cutting our own throats. I sum it up as "becoming too clever too quickly" and I defy anyone to say otherwise.

EDITORIAL COMMENT AND ADDENDUM

This article was commissioned in 2005 by the editors while on board R.V. Aplysia, one of the University Marine Biological Station's research vessels, of which Howard McCrindle was Skipper. The commissioning was then continued during the progress of an "evening session", in which much was revealed by Howard. The article is a truly fascinating account by a dedicated professional fisherman and skipper, who knows the west coast of Scotland and its fisheries better than anyone we know. He is also a very good friend who has done much for fisheries in developing countries.

What Howard has not revealed in his unique story, is how he recently almost drowned while collecting food alone - amongst rocks between tide-marks late at night on the Isle of Cumbrae. We understand that this was followed by a memorable encounter with cows as he tried to return to *terra firma*. A lesson to us all.

Azra and Peter Meadows.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 83-108.

SEDIMENT PATTERNS OF THE INTERTIDAL ZONE IN THE FIRTH OF CLYDE: VISUALISATION OF BIOLOGICAL, CHEMICAL AND PHYSICAL EFFECTS

Azra Meadows[1], Peter S. Meadows[1], Hugh Flowers[2], and Naureen Qureshi[3]

[1]Division of Environmental and Evolutionary Biology
Institute of Biomedical and Life Sciences,
University of Glasgow
Glasgow G12 8QQ
Email: gbza31@udcf.gla.ac.uk

[2]Department of Chemistry
University of Glasgow
Glasgow G12 8QQ
Email: hughf@chem.gla.ac.uk

[3]Centre of Excellence in Marine Biology,
University of Karachi,
Pakistan.
Email: <naureenaziz@yahoo.com>

ABSTRACT

Intertidal environments consist of rocky, sandy, and muddy ecosystems. The sandy and muddy ecosystems together constitute intertidal sedimentary ecosystems. These are all dynamic environments that are affected by physical, chemical and biological processes, and they experience a number of changes during each diurnal tidal cycle and are also affected by lunar and seasonal changes. In sedimentary ecosystems, these include physical changes in sediment patterns due to water current and wave action, which form sand bars and ripples. Within the sediment column, particle size and packing affect the shear strength, pore size and water content of sediments. Chemical processes such as the oxidation-reduction potential (Eh) and the pH of the sediment determine the aerobic state of sediments. The activities of microorganisms in breaking down organic matter also play an important role. This is particularly noticeable during macroalgal decomposition.

Infaunal and epifaunal invertebrates, together with a number of vertebrates play a central role in the functioning of the intertidal sedimentary ecosystem. Their biological activity in and on sediments contributes significantly to the modification of the physical and chemical properties of sediments, and conversely the physical and chemical properties of sediments often determine which biological groups colonise and are active in these environments. This is an interacting system, in which benthic organisms ranging from microorganisms to macrofauna, fish, and birds affect the physical and chemical state of sediments, and the physical and chemical state of the sediments affects the biological activities of microorganisms, macrofauna, fish and birds.

In this paper we describe results of long term studies of an intertidal region at Ardmore Bay in the Clyde estuary, our objectives being to review for the professional and amateur marine scientist the muddy sandy environments that together make up the intertidal sedimentary ecosystem. The work reported here has been conducted over many years by members of the Biosedimentology Unit at the University of Glasgow, together with colleagues from the Department of Civil Engineering, and recently from the Department of Chemistry, and from the Centre of Excellence in Marine Biology at the University of Karachi, Pakistan. The paper illustrates some of the effects of physical, chemical and biological processes in a sedimentary context, highlighting the nature of sediment patterns as a principal consequence of sediment-benthos interactions.

INTRODUCTION

Intertidal zones between high and low tide are one of the most easily accessible, and also one of the most varied marine environments associated with the coastal zone. They range from steep rocky outcrops, to sandy and muddy beaches, shingle and saltmarshes, and contain a wealth of micro-environments and of animal and plant species (Reise, 1985; Meadows & Campbell, 1988; Mathieson & Nienhuis, 1991; Little & Kitching, 1996). As a result, they have been a source of detailed scientific study since at least the early nineteenth century. Recent studies have addressed a host of important ecological questions, including studying the taxonomy and biology of meiofauna in sediments, investigating the nature of predator-prey relationships between macrobenthos on rocky shores, and analysing community structure and function (Cadee, 1976, 1979; Frostick & McCave, 1979; Newell, 1979; Carney, 1981; Grant, 1983; Reise, 1985; Jenkins & Rae, 1997; Black *et al.*, 1998; Horn *et al.*, 1999; Widdows *et al.*, 2000; Consalvey *et al.*, 2004; Olaffson & Paterson, 2004; Roast *et al.*, 2004; Consalvey *et al.*, 2005; Deloffre *et al.*, 2005; Armitage & Fong, 2006; Orvain *et al.*, 2006; Paarlberg *et al.*, 2005; Siebert & Branch, 2006).

One of the most interesting areas that are currently being analysed, is the way in which physical processes and biological activity define the temporal and spatial structure of the intertidal zone – especially in sedimentary environments. Many investigations show how wind force, current speed, tidal range, and the activities of birds,

fish, invertebrate macrofauna, meiofauna, and microorganisms interact with each other, to effectively determine this structure. These interactions are present on any intertidal area, however they are especially obvious around the coasts of the Clyde sea area and Firth of Clyde this sentence needs modifying because of the varied nature of exposed and sheltered environments in the region.

In the current paper we provide a series of examples and interpretations of physical, chemical and biological effects that are readily observable by close inspection of the surface and infrastructure of sediments, our aim being to provide for the non-specialist a guide to patterns on the sediment surface and their biological and physical causes. In order to do this, however, we need to provide a general background to some of the detailed processes that interact together in the intertidal zone, based on our work in the Firth of Clyde and Clyde Sea area.

Over a period of 30 years, we and our colleagues have been studying intertidal sedimentary ecosystems at Ardmore Bay and related intertidal ecosystems in the Firth of Clyde and have built up a comprehensive understanding of the physical, chemical and biological processes and their interactions occurring in these ecosystems (Meadows & Tait, 1985, 1989, Tufail, 1985; Meadows & Tufail 1986; Meadows & Shand, 1989; Tufail *et al.*, 1989; Meadows *et al.*, 1990; Muir Wood *et al.*, 1990; Meadows & Hariri, 1991; Meadows & Meadows, 1991; Meadows *et al.*, 1994; Muir Wood *et al.*, 1995; Meadows *et al.*, 1998a, 1998b; Shaikh, *et al.*, 1998; Carrasco *et al.*, 2002; Murray *et al.*, 2002). In this paper, therefore, we use Ardmore Bay as a source of material that will enable non-specialists to understand some of the complex processes and interactions occurring in and on sedimentary environments of the intertidal zone more generally.

MATERIALS AND METHODS

The materials and methods that have been used to produce most of the data presented in this paper have been described in detail elsewhere, and are too complex to cover fully here (Meadows & Tufail 1986; Meadows & Shand, 1989; Meadows *et al.*, 1989; Tufail *et al.*, 1989; Meadows *et al.*, 1990; Muir Wood *et al.*, 1990; Meadows & Hariri, 1991; Meadows & Meadows, 1991; Meadows *et al.*, 1994; Muir Wood *et al.*, 1995). However a brief summary of the main points will be of help.

Standard intertidal survey techniques of quadrat sampling using quarter metre quadrats, together with line transects have been Employed. Shear strength, redox potential, pH, particle size, pore size and the abundance of infaunal species of invertebrates are measured in the quadrats and along the line transects. These provide information on the detailed physical and chemical properties of the sediments and of the infaunal species.

Shear strength, which is a measure of the binding capacity, cohesion or strength of the sediment is measured at the surface of the sediment using a Geonor fall cone apparatus, and down the sedimentary column using a Pilcon vane. The Geonor fall cone releases a metal cone onto the surface of the sediment, and the depth of penetration of the cone into the sediment is measured. The Pilcon vane apparatus consists of a crossed vane on the end of a long metal rod. This is pushed progressively into the sediment, readings being taken every 5 to 10 cm vertically, by measuring the torque or twist needed to break the sediment, readings being taken on a circular torque disc at the top of the rod. Field data from both pieces of apparatus are converted to kN/m^2 using standard equations. The units kilo Newton can be seen to be force per unit area, in other words they are technically a pressure. This pressure is the pressure that is required to break the surface of the sediment using the Geonor fall cone, or to fracture the sedimentary column using the Pilcon vane. At a very practical level, the deeper one's boots, bucket or walking stick penetrate the sediment, the lower the shear strength.

A quantitative assessment of the pore sizes in the interstices of the sediments, including the burrows of any small invertebrates living in the sediment can be estimated by water release curves. Water release curves were measured on intact sediment cores collected from the upper intertidal region at Ardmore Bay. The cores were collected using 83 mm ID by 55 mm tall glass core sleeves. In the laboratory, the cores were mounted on a Haines apparatus (Haines, 1930) consisting of a 100 mm ID grade 4 porosity sintered glass Buchner funnel connected to a burette manometer. Fine, acid washed sand was used beneath the sediment core to ensure good contact between the sediment core and the sintered plate. The core was saturated with seawater and measurements of water content were made up to water potentials of –10kPa. The water release curves were used to calculate pore size distributions.

The Eh (oxidation-reduction) or redox potential of sediments is measure of the oxidising or reducing nature of the sediment. Sediments at or near the surface are usually highly oxidised or aerobic. As one progresses down the sedimentary column, the sedimentary environment becomes progressively more anaerobic. The change occurs at different depths ranging from a few millimetres to many centimetres in the intertidal zone. The change is most obvious to the casual observer as a darkening of the sediment from light brown to dark brown or black, and when black as the smell of hydrogen sulphide – rotten eggs. Most larger invertebrates that burrow into sediment aerate their burrows by ventilating them with seawater from the water column when the tide is in. If they did not do this, they would be unable to live in the more anoxic layers of the sediment. However a number of highly specialised bacteria, the anaerobic bacteria can live under these conditions, and some can only survive under these conditions. A typical representative is the sulphate reducing bacterium *Desulfovibrio delsulfuricans*. The redox potential of a sediment is therefore an important parameter to measure in terms of assessing the overall oxidised or reduced nature of the sediment. It is also an indirect measure of the total organic content of a sediment, because the more organic material in the sediment the more anaerobic it becomes – by microbial

leading to the decomposition of the organic material. Redox potential is measured using standard Eh electrodes and an Eh meter.

The pH or alkalinity f sediments is also important, but does not vary so much as Eh. It is measured using pH electrodes and a pH meter. Together, Eh and pH provide a useful quick assessment of the aerobicity and alkalinity of sediments, and Eh-pH diagrams are used to provide a visual picture of the chemical state of sedimens both intertidally and in sea water.

Particle size of sediments is measured by sieving dried sediment through a series of standard sieves of decreasing mesh size, the weight of sediment on each sieve then being used to provide statistics on the mean particle size, sorting, skewness and kurtosis of the sediment sample.

Infaunal invertebrates are sieved from fresh wet sediment using a sieve whose mesh size is 750 microns. The species are identified, and the number of individuals in each species counted to give estimates of abundance.

Some of the work referred to below derives from a detailed analysis of the chemical, physical and biological features of quarter metre quadrats that were taken along two fifty metre transects. The first of these was established in the upper intertidal region and covered a number of algal patches and patches of bare sediment. The second was established in the lower intertidal region, and was sited to cross three peaks and the two intervening troughs of the large sand waves there. These are referred to as the high tide and low tide sites.

RESULTS

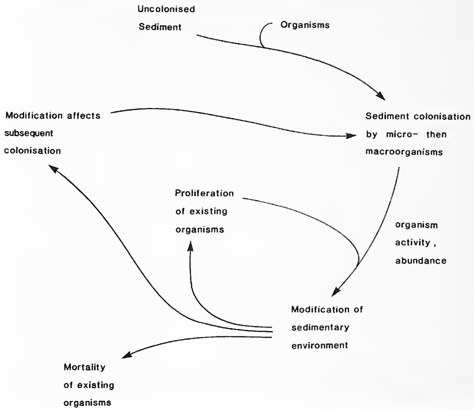
The nature of the sedimentary ecosystem

The simplest way of understanding how physical, chemical and biological interactions occur is to consider what happens when an uncolonised sediment is initially colonised by living organisms (Meadows & Tufail 1986) (Figure 1). The first step is for photosynthetic autrotrophic and heterotrophic microorganisms from the overlying water and surrounding sediments to be carried into the sediment by water moving through the pore water near the surface of the sediment. This initial colonisation is followed by the invasion of the sediment by the protozoa and very small invertebrate species that constitute the meiofauna. The meiofaunal species range in size from about 60 microns to a maximum of about 2 mm. Finally larger invertebrates colonise the sediment either as larvae settling on or in the superficial layers of the sediment, or by adult invertebrates burrowing into the sediment and constructing vertical and horizontal burrows. These are mainly annelids, molluscs and crustacea.

The bacteria, micro-algae, meiofauna and macrofauna modify the sediment by producing chemical extracellular polymeric materials (mucus), by feeding on organic material, and the larger macrofaunal invertebrates move through the sediment or construct burrows downwards into the sediment. These macrofaunal invertebrates include such organisms as the polychaete rag worm *Hediste (Nereis) diversicolor*, the crustacean mud shrimp *Corophium volutator*, and the edible cockle *Cerastoderma (Cardium) edule* and the mussel *Mytilus edulis* both of which are bivalve molluscs. All of these species alter the physical packing of the sediment, its water content and shear strength, its permeability and its Eh and pH. The organisms themselves proliferate, and many are eaten or die naturally, further complicating microscale ecological patterns within the sediment fabric.

The sedimentary ecosystem with its complex of interacting physical, chemical properties and its biological communities is an integrated whole, that varies from place to place in the intertidal zone, depending on organic input, degree of exposure, particle size, fresh water input and vertical position in the tidal zone. It can be viewed as a sediment benthos system in which all parts affect each other (Meadows & Tufail, 1986) (Figure 2). The abundance and activity of the microorganisms, meio and micro fauna and macrobenthos (invertebrates and macroalgae), interact and modify the chemical and physical processes taking place within the sedimentary column, and vice versa. This system in turn exports and imports organisms and chemicals to and from the overlying water column. The system is therefore complex, and even now its details are only understood in outline, as Murray *et al.*, (2002) have pointed out recently. These authors consider the global scale of the system in all marine environments, ranging from the intertidal zone, through the continental shelves surrounding the major land masses, to the abyssal plains that cover half of the planet. They also draw attention to the importance of considering microscale effects and their impact on ocean ecosystems, and to the central role played by the extracellular polymeric material (mucus) secreted by many organisms that live on the sediment surface and within the sediment fabric.

Figure 1. Colonisation by biological species and the subsequent effects of biological activity on the sedimentary environment (Meadows & Tufail, 1986).

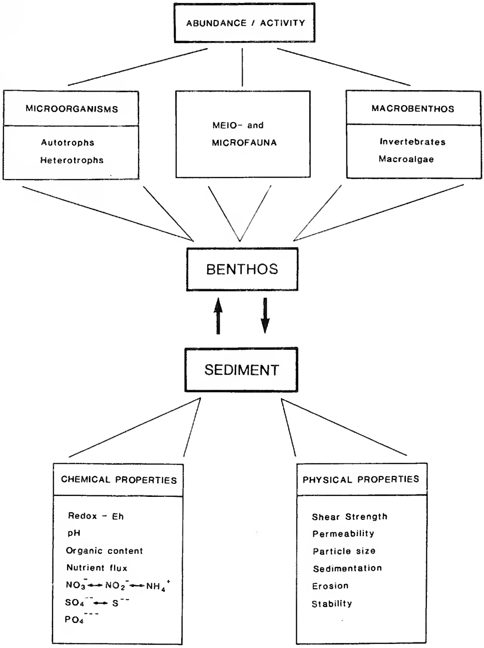


Ardmore Bay

Ardmore Bay, where many of the observations and measurements referred to in this paper have been made, is on the northwest side of Ardmore Point on the northern side of the Clyde Estuary near Helensburgh (National Grid NS 320 792). It has a number of distinct sedimentary ecosystems within it that provide a natural laboratory in which to conduct field experiments and to undertake surveys (Figure 3). Figure 4 shows the middle and lower intertidal zone of Ardmore Bay looking northwest towards low tide, with the town of Helensburgh in the distance. The very high abundance of the lugworm *Arenicola marina* is indicated by the large number of faecal casts of the lug worm *Arenicola marina* in the fore ground and middle ground. Figure 5 shows the middle and upper intertidal zone at Ardmore Bay, looking towards the east. The drainage channel down the beach, which is almost fresh water is clearly visible. Lugworm *Arenicola marina* casts are obvious in the foreground middle intertidal zone. Small rocks, erratics are visible in the upper intertidal zone of the beach in the middle distance. Figure 6 is a close-up view of the upper intertidal zone, looking towards the east. Is the following sent. Needed? The white house in the middle distance at the left can be seen in figure at the far left. The high tide zone is bounded by the salt marsh which is clearly visible in the middle of the photograph, with its saltings cliff about one metre high, separating the marsh from the intertidal low energy sedimentary ecosystem in the foreground.

In summer, the upper part of the intertidal bay is covered by patches of macroalgae – *Enteromorpha*, and the following is not seasonal by small boulders between half a metre and one metre in diameter. These latter are probably erratics left by retreating glaciers at the end of the last ice age. The patches of algal mats are one to five metres in diameter, and grow to this size in summer not sure of the following from underlying material. They die down in winter, but can still be located just below the sediment surface in a decayed state The Eh and pH of the algal and adjacent non-algal patches are significantly different, and this is associated with different biological communities that have been analysed in detail by Tufail *et al.*, (1989).

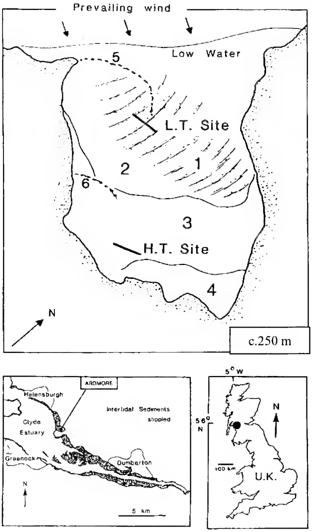
Figure 2. A model for the sediment/benthos ecosystem (Meadows & Tufail, 1986).



The middle region of the bay that occupies the central intertidal zone, is flat and contains a very large population of the mud-burrowing polychaete lugworm *Arenicola marina*, whose casts are highly visible at the sediment surface. The animal, which lives in a U-shaped burrow, feeds on small organisms and organic matter in the sediment that it takes in at the inhalant end of the U tube. It then excretes the sediment at the exhalent end of the U tube. The animal's faecal casts are most obvious when calm weather follows a storm. This may be because the storm causes wave action which fills the U tube with sediment that the animal then eats and excretes onto the sediment surface. The biology and ecology of Arenicola marina are described in detail by Wells (1945), and very recently by Tyler-walters (2006) who also provides key references for the species over the last 100 years.

The lower part of the intertidal zone in the bay has a number of large sand waves or dunes whose position is constant from year to year. The sand waves are covered twice a day by the diurnal tides and when not covered by the tide, except on very hot summer days. They are almost certainly produced by wave action caused by the prevailing westerly winds. The waves are a very characteristic feature of this part of the beach, and their sediment is coarser and more aerobic than sediment in the middle and upper intertidal zone of the beach. The troughs of the sand waves are almost always covered with one to five centimetres of sea water, even at low tide. The peaks of the sand waves are completely drained every tidal cycle. There is therefore a significant difference between the communities of animals that live in these two sedimentary ecosystems – the troughs and the peaks of the sand waves (Tufail *et al.*, 1989).

Figure 3. Location of the Clyde Estuary in the UK (right hand lower map), and of Ardmore Bay in the Clyde Estuary (left hand lower map). The upper map shows the general shape and main areas of Ardmore Bay. L.T. Site = site of the lower intertidal 50 metre transect. H.T Site = site of upper intertidal 50 metre transect. The lengths of the transects are exaggerated on the diagram to show their position.
1= area of sand waves. 2 = area of flat sand. 3 = area of algal mats and muddy sand. 4 = area of algal mats and muddy sand interspersed with small boulders. 5 and 6 = two rows of boulders that are almost certainly man-made. These are probably fish traps (yairs). (Tufail *et al.*, 1989)



Tufail *et al.* (1989) conducted a detailed analysis of the high tide and low tide regions of Ardmore Bay, by sampling along two 50 metre transect lines at one meter intervals. The differences between the two areas are very distinct, the high tide region being dominated by the algal mats, and the low tide region by the large sand waves. This is also apparent in the levels of the water table at the two sites.
The authors measured shear strength, redox potential, and the abundance of eight species of macrobenthic invertebrates inhabiting the sediment. Statistical correlation analyses and variance ratio tests of the relationships between the abundance of the macrofaunal invertebrates, redox potential and shear strength, showed interesting patterns. Variability between sediment parameters and between species abundance was higher at high tide than at low tide. However there were fewer significant correlations between sediment parameters and species abundance at high tide than at low tide.
The measured abundances of the individual species allowed diversity indices (Shannon Weiner and Simpson) to be calculated for the animal communities in the two areas of the beach. Community diversity as measured by these two indices was higher along the high tide transect than along the low tide transect. This may have reflected the greater availability of food in the form of organic material and small meiofauna at the high tide transect. There was more variability in the indices at the low tide transect than at the high tide transect. This is probably caused by the relatively large vertical difference between the peaks and troughs of the large sand waves.

Figure 4. The middle and lower intertidal zone of Ardmore Bay looking northwest towards low tide, with the town of Helensburgh in the distance. The very high abundance of the lugworm *Arenicola marina* is indicated by the large number The faecal casts of the lug wogrm *Arenicola marina* in the for ground and middle ground.

Figure 5. The middle and upper intertidal zone at Ardmore Bay, looking towards the east. The drainage channel down the beach, which is almost fresh water is clearly visible. Lugworm *Arenicola marina* casts are obvious in the foreground middle intertidal zone. Small rocks, erratics are visible in the upper intertidal zone of the beach in the middle distance.

Figure 6. The upper intertidal zone at Ardmore Bay, looking towards the east. Close-up view. The white house in the middle distance at the left can be seen in figure at the far left. The high tide zone is bounded by the salt marsh which is clearly visible in the middle of the photograph, with its saltings cliff about one meter high, separating the marsh from the intertidal low energy sedimentary ecosystem in the foreground.

Figure 7. The common mussel, *Mytilus edulis*, growing on sediment and small boulders on the north side of Ardmore Bay.

Physical and chemical patterns in sediments

Figure 8 shows the difference in the topography of the upper intertidal and lower intertidal areas of the beach along the two fifty metre transects (Tufail *et al*., 1989). The peaks and troughs of the large sand waves in the lower intertidal region of the beach are obvious, and can also be seen in the upper map in figure 3. This demonstrates clearly that the high tide area is relatively flat compared with the large vertical variation in sediment height across the peaks and troughs of the sand waves in the low tide area.

The formation of sand bars, sand waves, and sediment ripples under water has received intense study over many years. However it is still not clear why these structures develop, except to state that they are caused by an interaction between the velocity of water currents in the boundary layer above the sediment and the sediment surface itself. There is also a very significant effect of sediment particle size. Finer sediments form sediment waves or ripples at much slower water velocities than coarser sediments. Furthermore as the velocity increases, the waves and ripples are flattened again. A similar effect occurs at the air-water interface at sea, where waves are produced by wind action up to a wind speed of about force 9 or 10, only to be flattened as the wind increases to force 11 and beyond – a sobering experience for those who have oceanic sea experience in research vessels.

At a very local level, and at relatively low horizontal water velocities, ripples are often present on sand in the intertidal zone. Figures 9 and 10 illustrate this at Ardmore Bay. Figure 9 shows ripples of wavelength c. 7.14 cm, that have been formed in the middle of the intertidal zone. The tops of these ripples have been flattened subsequent to their formation, both the formation and subsequent flattening taking place during the period that the sediment is covered by water. The close-up photograph in figure 10 is interesting. It shows unusual microscale erosion channels that appear to be developing along the top of the ripples. These are at a frequency of c. 1.2 cm, and may represent the initiation of ripple migration distruction or flattening. The phenomenon needs further investigation. There is also an asymmetry of the ripples in this photograph with the slopes to the right of the peaks being longer and of lower angle than those to the left of the peaks. This effect is most obvious in the left and right of the central ripple peak. This may represent the beginnings of ripple migration towards the left, with avalanching taking place down the steeper face.

Figure 11 shows profiles of sediment shear strength in an algal mat area (left hand graph. Labelled A), and a non-algal mat area (right hand graph, labelled NA), on the transect in the upper intertidal region. In this figure, the upper line (full circles) in each graph is the peak shear strength (an initial reading at each sediment depth). The lower line (full squares) in each graph is the residual shear strength (a second reading at the same depth, taken immediately after the first). The increase in shear strength into the sediment is a characteristic of most marine sedimentary environments, and at Ardmore Bay is similar on all parts of the beach.

The pore size distribution obtained from field cores in the laboratory using Haines apparatus shows a small number of relatively large pores (>0.2 mm diameter) with the main distribution centred at 0.05 mm diameter down to the limit of the measurements at 0.025 mm diameter These pores corresponded to 11% of the total core volume (Figure 12). The small number of large pores probably represents the U shaped burrows of the mud shrimp, *Corophium volutator*. The smaller pores may be burrows excavated by small immature Corophium, or by larger meiofauna. The role of meiofauna in this context was reviewed by the late Alan Reichelt in a seminal review article (Reichelt, 1991). Reichelt states that burrow formation in sediments is only known for a few groups of meiofauna, including species of burrowing copepods, nematodes, and tanaids. However these groups can occur in enormous numbers in sediments (Murray *et al*. 2002), and they probably play a very significant role in ventilating sediment both intertidally and in the subtidal. Water release curves as measured in the current paper, provide a quantitative assessment of the pore sizes in the interstices of the sediments which will include animal burrows, although in the field cores from Ardmore Bay the burrows do not appear to be behaving as simple cylinders, U-shaped or otherwise. The matter needs further analysis.

The redox characteristics and pH of the sediment is very different between the upper intertidal area and the lower intertidal area (figure 13). In the former, the presence of the algal mats provides additional heterogeneity. Within the algal mats, the sediment just below the surface has a very low Eh and is more acidic than sediment in the bare areas of the adjacent sediment. The effects of the low Eh are clearly visible as a very black layer of sediment just underneath the algal mats (Figure 14), where the previous year's growth of algae has been covered by sediment during the winter, and then becomes anaerobic by bacterial action on the decaying seaweed. The Eh of the sediment at low tide on the peaks of the sand waves is high, and the sediment has a more alkaline pH approximating to that of the overlying sea water.

Figure 8. Fifty-metre long transects at high tide and low tide, Ardmore Bay, showing level of water table in relation to the sediment surface. The difference between the two sites is very clear, with the low tide site being dominated by the large scale sand waves, whose wavelength is approximately 25 metres and amplitude approximately 20 cm. (Tufail *et al.*, 1989)

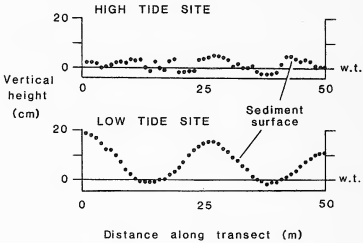


Figure 9. Small scale ripples on the middle of the intertidal zone and Ardmore Bay. The meter stick gives the scale. The wavelength of the ripples is approximately 7.14 cm. The tops of the ripples have been flattened by water movement subsequent to their formation. Both these events occur when the sediment is covered with water.

Figure 10. Close up photograph of ripples in the middle of the intertidal zone at Ardmore Bay. The ten pence piece, 2.5 cm diameter, gives the scale. The photograph, taken at a low angle of the sun, is approximately one-to-one. Note the interesting pattern of repeated micro-erosion channels at the top of the ripples. There are about 12 of these per 10 cm of ripple peak. Note also the asymmetry of the ripple, the slopes to the right of the two peaks being longer and of lower angle than those to the right of the peaks. This effect is most obvious in to the left and right of the central ripple.

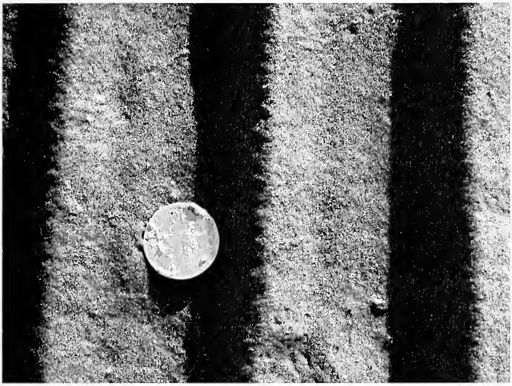


Figure 11. Profiles of sediment shear strength in an algal mat area (left hand graph. Labelled A), and a non-algal mat area (right hand graph, labelled NA), on the transect in the upper intertidal region.
x axis: depth into the sediment in cm. y axis: shear strength in kiloNewtons/metre^2.
The upper line in each graph is the peak shear strength (an initial reading at each sediment depth). The lower line in each graph is the residual shear strength (a second reading at the same depth, taken immediately after the first).

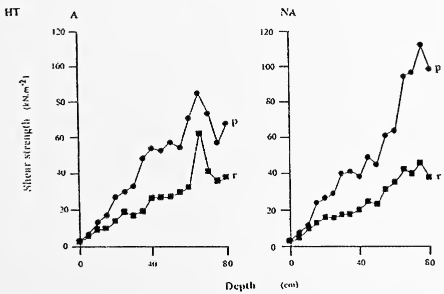
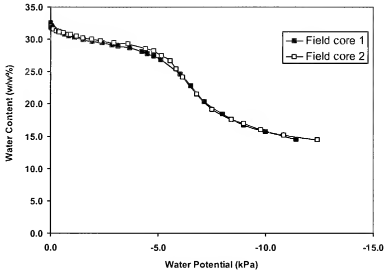


Figure 12. Moisture release curve (upper) and pore size distribution (lower) for two field cores, measured in the laboratory using Haines apparatus (Haines, 1930). The cores were obtained from the upper intertidal region in Ardmore Bay where mud shrimp, *Corophium volutator*, are abundant. The high values for pore volume at the extreme left hand side of the lower graph are probably caused by the burrows of adult mud shrimp *Corophium volutator*.
The relationship between the x axis values of water potential in the upper graph, and the x axis values of diameter classes in the lower graph (histogram) is a negative exponential. So the difference between the absolute sizes of the diameter classes on the x axis in the lower graph decreases exponentially from left to right along the histogram.



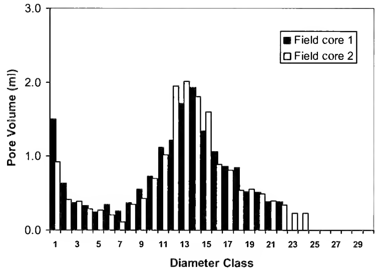


Figure 13. Eh/pH diagrams for the high tide site and low tide site at Ardmore Bay (Meadows and Tufail, 1986). The left hand diagram shows high tide data from algal mat and non-algal mat areas. The right hand diagram shows low tide data from the peak of a sand wave – the dune.

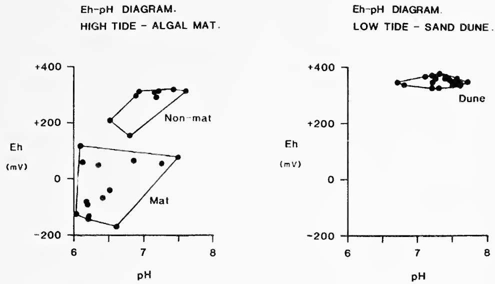
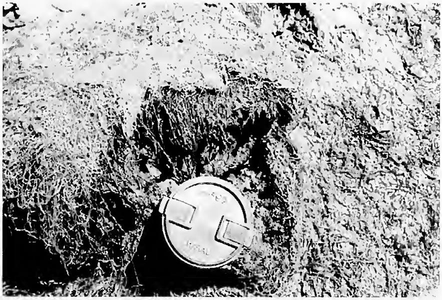


Figure 14. Algal mat growing on the surface of sediment in the upper intertidal region at Ardmore Bay. The intact algal mat at the sediment surface is around the upper part and periphery of the photograph, and in nature is a bright green. The highly anaerobic sediment and subsurface algal mat is in the centre and lower part of the photograph, and in nature is black. Scale is given by the camera lens cap, which is 5cm in diameter.



Biological patterns in and on sediments

Biological patterns in and on sediments at Ardmore Bay are distinctive, although many of them can be seen on other intertidal zones around the UK. They fall into two general categories, those that can be seen on the surface, and those that can only be seen when the sediment is dug into or cored. There is a very wide range of size in both categories These range from chains of microbial cells within the sediment itself that may be no more than 10 microns long (1000 micron = 1mm), to much larger scale modifications of the sediment surface which may extend for a metre or more.

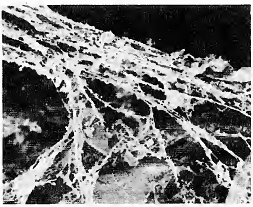
We firstly describe the smallest effects that we have recorded, and then illustrate progressively larger sized biological patterns. One of the most dramatic points that becomes immediately apparent, is that the effects of

biological activity and the resultant patterns in or on the sediment are clearly visible at all scales – even if it may need a scanning electron microscope or light microscope to visualise them. Figure 15 shows some of the microscopic effects. The left hand photomicrograph shows the network of secretions that are produced by a number of burrowing organisms, in this case the ragworm *Hediste (Nereis) diversicolor*. Sand grains can be seen in the lower part of the photomicrograph (Meadows *et al.*, 1990). These secretions consist of extracellular polymeric material, or mucus, that bind sediment particles together. They are often used by animals during the construction of their burrows. The right hand photomicrograph shows a typical community of microorganisms that grows at or just below the sediment surface (Meadows & Tufail, 1986). In this instance the two types of microorganisms are photosynthetic, the rope-like blue green algae and the barrel-shaped diatoms.

At a slightly larger scale within the sediment, burrows produced by invertebrate infauna that live in the sediment column can be demonstrated by using resin casts, and also by breaking a sediment using a spade on the shore. Figure 16 is a photograph of a resin impregnation of sediments from an intertidal area at Langbank on the southern shore of the Clyde Estuary, a little upstream from Ardmore Bay (Meadows & Tufail, 1986). The resin cast shows the complex system of burrows below the surface, even in this sediment where there are only three or four species.

Many of the biological structures and the burrows of individual animals can be observed by digging into the sediment. This is most effectively done by pushing a spade into the sediment at an angle of about 30 degrees from the vertical, and then breaking the sediment by levering the spade downwards towards you, until it lies almost flat. Figures 17 and 18 illustrate burrows exposed in this way. Figure 17 shows a natural burrow of the ragworm *Hediste (Nereis) diversicolor* on Ardmore Bay. The burrow runs vertically into the sediment and usually has one to three openings to the surface. The animal that constructed the burrow can be just seen in the burrow below the lens cap. The dividing line between the lighter aerobic sediment and the darker anaerobic sediment is termed as the Redox Potential Discontinuity Layer (RPDL) (Jickells & Rae, 1997). Redox potential decreases rapidly in this region, and the dark anaerobic layer is anaerobic enough for strictly anaerobic microorganisms to live there. Figure 18 illustrates natural burrows of the mud shrimp *Corophium volutator* on Ardmore Bay. The U shaped burrows run vertically into the sediment, and have two openings to the sediment surface – the tops of the U. The tops of the U are 1.0 to 2.1 cm apart in burrows constructed by adult animals. The darker sediment at the bottom of the exposed sediment section is anaerobic. The Redox Potential Discontinuity Layer separating the lighter aerobic sediment and the darker anaerobic sediment is again clearly visible.

Figure 15. Scanning electron microscope photomicrographs from Clyde Estuary sediments (Meadows & Tufail, 1986). Left hand photograph: particle binding secretions produced by the ragworm Hediste (Nereis) diversicolor (Meadows *et al.*, 1990); scale bar = 100 microns. Right hand photograph: blue green algae (rope-like structures) and diatoms (barrel shaped objects) in sediment interstices (Tufail, 1985); scale bar = 50 microns.



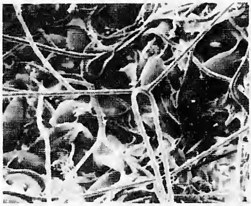


Figure 16. Resin impregnation casts of estuarine sediment from Langbank on the southern bank of the Clyde Estuary, slightly upstream from Ardmore Bay. 1 = the U-shaped burrows of the mud shrimp *Corophium volutator*. 2 = the deeper burrows of the ragworm *Hediste (Nereis) diversicolor*. 3 = a specimen of the burrowing bivalve, *Macoma baltica*. 4 = unidentified burrows, possibly of immature *Corophium volutator* or the small estuarine oligochaete *Tubifex costatus*. (Meadows & Tufail, 1986; Meadows et al., 1990).

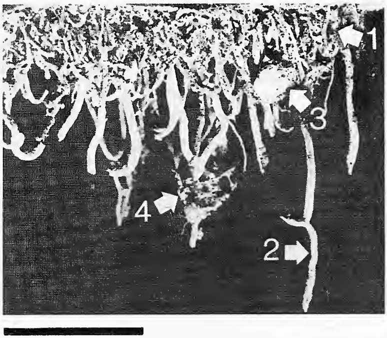


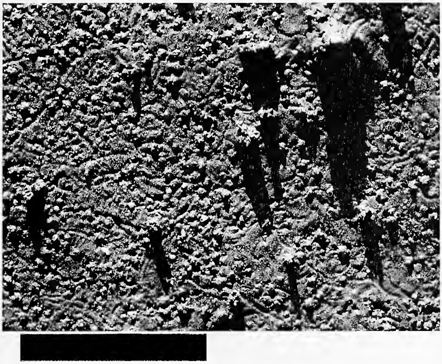
Figure 17. Natural burrow of the ragworm *Hediste (Nereis) diversicolor* on Ardmore Bay. The burrow has been exposed by pushing a spade into the sediment at an angle of about 30 degrees from vertical, and then breaking the sediment by levering the spade downwards until it lies almost flat. The scale is given by the camera lens cap which is about 5 cm in diameter. The burrow runs vertically into the sediment. The animal that constructed the burrow can be just seen in the burrow below the lens cap. The darker sediment in the lower part of the exposed sediment section is anaerobic. The dividing line between the lighter aerobic sediment and the darker anaerobic sediment is termed the Redox Potential Discontinuity Layer (RPDL).

Figure 18. Natural burrows of the mud shrimp *Corophium volutator* on Ardmore Bay. The burrows were exposed by pushing a spade into the sediment at an angle of about 30 degrees from vertical, and then breaking the sediment by levering the spade downwards until it lies almost flat. The scale is given by the camera lens cap which is about 5 cm in diameter. The U shaped burrows run vertically into the sediment, and have two openings to the sediment surface – the tops of the U. The tops of the U are 1.0 to 2.1 cm apart for each burrow. The darker sediment at the bottom of the exposed sediment section is anaerobic. The dividing line between the lighter aerobic sediment and the darker anaerobic sediment is termed the Redox Potential Discontinuity Layer.

Figures 19 illustrates the surface of sediment in the upper intertidal zone at Ardmore Bay as seen in close-up view. The low light angle enables the details of the surface structure to be seen clearly. The scale is approximately one-to-one. The larger raised cones are small casts of the lugworm *Arenicola marina*.casts. The smaller cones which cover the surface are the entrances to burrows of immature mud shrimps *Corophium volutator*.

Figures 20 and 21, taken during a Haines experiment, show that almost identical patterns of burrows develop in the cores that were taken from the field. In surface view (Figure 20) the larger holes are the openings of the U-shaped burrows of adult mud shrimp, *Corophium volutator*. The smaller holes are the openings of similar U-shaped burrows constructed by small immature *Corophium volutator*. Figure 21 shows how the internal structure and burrows mimic the field picture shown in figure 18.

Figure 19. Close up view of the surface of sediment in the upper intertidal zone at Ardmore Bay. The low light angle enables the details of the surface structure to be seen clearly. Theblack bar = 5 cm. The larger raised cones are the entrances to the burrows of adult mud shrimp *Corophium volutator*. The smaller cones which pepper the surface are the entrances to burrows of immature Corophium.



The polychaete lug worm *Arenicola marina* is very abundant on many intertidal muddy and sandy beaches, and also occurs subtidally. There are very large populations of *A. marina* on most parts of the intertidal region at Ardmore Bay (Figures 4, 5). The animal constructs a U-shaped burrow that on Ardmore Bay is between 15cm and 30 cm deep (Figure 22). The inhalant and exhalent entrances of the burrows – which are easily distinguished from each other by the pile of faeces at the exhalent entrance – can be seen on most parts of the beach. Burrows and animals can be seen by digging with a spade, however the digging process has to be done quickly because animals are adept at digging deeper into the sediment.
The animal usually lies at the bottom of the burrow when the burrow surface is exposed to the air. The difference in colour between the surficial aerobic sediment and the deeper anaerobic sediment can usually be seen quite clearly, especially towards high tide where the deeper sediment is very anoxic. The boundary between the two sediments is the Redox Potential Discontinuity Layer. The light aerobic sediment extends into the anaerobic layer as a cylinder around the burrow. This is because the burrow is ventilated by the actions of the animal, and oxygen in the water diffuses across the burrow lining. Animals feed sediment falling into the entrance area of the burrow as it ventilates the burrow. It passes the sediment through the gut, digesting organic matter and small organisms. The digested sediment is excreted as a coiled pile of faeces at the exhalent entrance to the burrow (Figure 23). The colour of this faecal sediment sometimes indicates that the animal has been feeding on sediment that has come from the anaerobic layers of the sediment, because it is dark brown or dark grey. As sediment is drawn into the inhalant entrance of the burrow, miscellaneous pieces of biological material such as small broken pieces of algae are taken in, and presumably eaten by the animal along with the sediment that it takes in (Figures 24 and 25).

Figure 20. Surface view of the sediment core that was used in the Haines apparatus (Haines, 1930). Two categories of burrow opening are clearly visible. The large ones are the openings of the U-shaped burrows of adult mud shrimp, *Corophium volutator*. The smaller ones are the openings of similar U-shaped burrows constructed by small immature *Corophium volutator*. These field cores when brought to the lab are completely drained of pore water.

Figure 21. Internal patterns of burrows of the core illustrated in figure 20. The burrows are those produced by the mud shrimp, *Corophium volutator*.

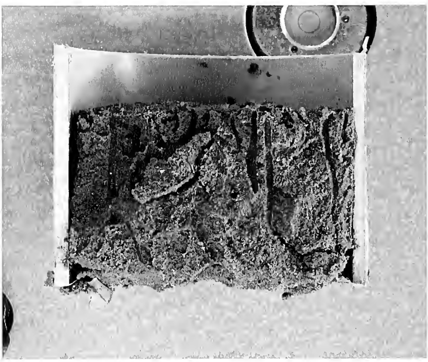


Figure 22. Diagram of large U-shaped burrow of the polychaete lugworm *Arenicola marina*. Note the inhalant and exhalent entrances to the burrow and the plug of faecal material, lying at the exhalent entrance. The animal usually lies at the bottom of the burrow when the burrow surface is exposed to the air. The difference in colour between the surficial aerobic sediment and the deeper anaerobic sediment is usually very obvious. The boundary between the two sediments, the Redox Potential Discontinuity Layer, is shown by the dashed line. The light aerobic sediment extends into the anaerobic layer as a cylinder around the burrow. This is because the burrow is ventilated by the actions of the animal, and oxygen in the water diffuses across the burrow lining. (Meadows & Campbell, 1988, p.119).

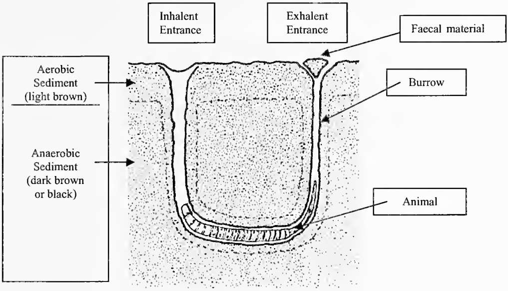


Figure 23. Pile of faecal sediment at the exhalent entrance of a burrow of the lugworm Arenicola marina. The ten pence piece (diameter 2.5 cm) gives the scale. The lower part of the pile has been eroded by water.
A small inhalant entrance (arrowed) with its surrounding cone can be seen indistinctly at the bottom left of the figure.

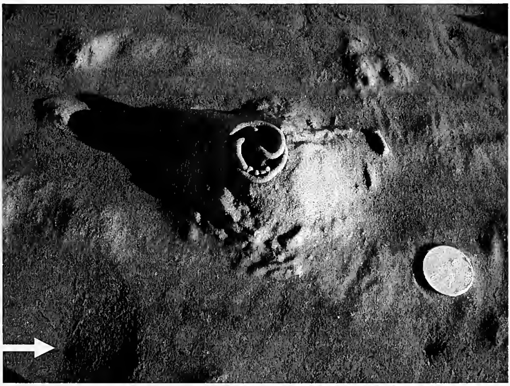


Figure 24. Inhalent entrance of the burrow of the polychaete lugworm *Arenicola marina* (bottom of the figure), at Ardmore Bay. Note the broken pieces of seaweed being taken into the burrow. Presumably the lugworm will ingest this with the sediment that it is eating. Note also the small then indistinct tubes. These are probably tubes of the small polychaetes *Pygospio elegans* or *Fabricia sabella*, both of which species are common on the intertidal at Ardmore Bay. The ten pence piece (diameter 2.5 cm) gives the scale.

Figure 25. Two inhalant burrows of the polychaete lugworm *Arenicola marina* at Ardmore Bay. The smaller tubes and small elevations on the sediment surface that are more obvious in the lower part of the figure are either the burrows of *Pygospio elegans* or *Fabricia sabella* (see figure 24). The ten pence piece (diameter 2.5 cm) gives the scale.

Traces made by organisms moving over or just below the surface of sediments are a common feature of muddy or sandy sedimentary environments in the intertidal zone, and these occur very regularly on the sediments at Ardmore Bay. The difficulty with these traces is that it is often unclear which type of organism or species has made them, unless one sees an individual in the process of making the trace. The trace illustrated in figure 26 is typical. It is clearly a trail caused by a small organism moving over or just below the sediment surface. The species is likely to be a small polychaete annelid or nemertine. Alternatively, it may be the surface trail of the small mud burrowing bivalve *Macoma balthica* that moves through the sediment just below the sediment surface. However the movement trails of *Macoma balthica* are usually gently curved – as seen in figure 30.
Macroalgae or seaweeds sometimes leave traces at the sediment surface. These are algal species that are either attached to small stones at the surface of the sediment, or that have been removed from intertidal rock surfaces by heavy wave action. As the algae lie on the surface of the sediment and are exposed to the flow and ebb of the tide, they are moved by the water and waves. When there is a reasonable depth of water above them, they float in the water column. As the tide falls and the water depth decreases, the plant lies on the sediment surface. It is at this point that the plant makes marks on the sediment surface caused by the receding tide moving the plant backwards and forwards. The resultant marks, which often appear like random scratches at the surface of the sediment, are not uncommon at Ardmore Bay, but are very obvious when seen. Figure 27 shows *Fucus* spp. probably *Fucus vesiculosus*, attached to a small boulder in the middle intertidal zone at Ardmore Bay. Streak marks on the sediment surface were made by the plant being moved by water as the tide receded. The weight of the plant has been enough to erode the ripples that are present elsewhere on the sediment surface.

Figure 26. Movement trail of an organism that has recently moved across the surface of the sediment. Ardmore Bay. The movement trace is about 3 mm in diameter. The organism that made trail is not known. It may be a small polychaete or nemertine, or possibly the small mud-burrowing bivalve Macoma baltica. The ten pence piece (diameter 2.5 cm) gives the scale.

Fish and birds also disturb the surface of the sediment, during feeding or while moving over the sediment under water, or when the tide has receded (Fog, 1967; Thiel, 1981; Madsen, 1988; Cadee, 1990; Cadee *et al.* 1994; Iribarne *et al.*, 2005). Small aggregations of shell material such as those shown in figure 28, have been seen from time to time on the intertidal zone at Ardmore. It is likely that these represent shell material regurgitated by birds Zonfrillo (personal communication 2004). In a recent email (Zonfrillo, personal communication 2007) he states "I'd think Gulls (Herring, Great Black-backed) might be responsible for regurgitating that cockle debris. Eider are another possibility. Shelduck eat mainly *Hydrobia*, but Eiders can handle *Mytilus* and probably small cockles in the gizzard, though usually it will come out the other end, they don't normally produce pellets!. If gulls use that area then it is more likely to be a coughed-up gull pellet, a Great Black-back (my best guess) will have the gizzard capable of grinding up thick shells. Sometimes they will swallow small stones to aid the process. I've found that kind of shell material, and starfish, in them elsewhere." Based on Zonfrillo's views and observations by the authors of birds feeding in the intertidal zone at Ardmore (Figure 29), the regurgitated material probably comes from one of the gull species.

Figure 27. *Fucus* spp. probably *Fucus vesiculosus*, attached to a small boulder in the middle intertidal zone at Ardmore Bay. The small boulder is at the top of the figure. Marks made by the plant being moved by water movement as the tide receded are obvious. The weight of the plant has been enough to erode the ripples that are present elsewhere on the sediment surface. The ten pence piece (diameter 2.5 cm) just below the centre left, gives the scale.

Figure 28. Shell material either regurgitated or faecal. Largely consisting of fragments of the edible cockle *Cerastoderma (Cardium) edule.* The ten pence piece (diameter 2.5 cm) gives the scale.

Figure 29. Gull or duck footprints on the sediment surface in the upper intertidal region at Ardmore Bay. The curved track is made by the small bivalve Macoma balthica moving through the sediment just below the surface. The ten pence piece (diameter 2.5 cm) gives the scale.

The surface markings in the upper intertidal zone shown in figure 30 are probably caused either by benthic feeding birds or benthic feeding fish. Zonfrillo (2007 – personal communication) considers them to be caused by birds. Cadee (1990) records such patterns that of Black Headed gulls *Larus ridibundus* and Shelducks (*Tadorna tadorna*). Black Headed gulls make troughs up to 3 metres long and about 15 cm wide – this is very similar to the markings in figure 30. Shelducks make craters about 10 cm deep and up to 60 cm in diameter, and Eider ducks (*Somateria mollissima*) make similar craters. Cadee (1990) also records craters made by rays (*Hypotrema*), flounders (*Platichtys flesus*) and bream (*Abramis brama*). The authors of the current paper therefore consider that the most likely cause of the surface markings shown in figure 30 are either feeding troughs produced by Black Headed Gulls or feeding traces made by young ray or flounders,

Figure 30. Surface markings in the upper intertidal at Ardmore Bay. Either caused by benthic feeding fish or birds. See text for further details. The scale is given by the metre stick.

CONCLUSION

In this paper, we have attempted to provide an overall view of the intertidal sediment ecosystem together with a description of the complex web of physical, chemical and biological interactions that make it so interesting. It has been our objective to provide an account that allows the non-specialist to appreciate this complexity, and to visualise some of the effects that are obvious to a trained eye on one particular shore, Ardmore Bay, adjacent to and just northeast of Ardmore Point, in the Clyde Estuary. Visualisation is very important to the specialist as well as the non-specialist. Both can learn a great deal about a particular sedimentary ecosystem by walking over it, looking at it, and digging into it.

We began by taking a very general view of the organisms that live in or on sediments and how they colonise and modify the physical and chemical properties of the sediment (Figures 1 and 2). The geography of Ardmore Bay, and its general characteristics are shown in figures 3 to 7. The physical and chemical patterns in and on sediments are sometimes only demonstrable by field or laboratory experiments. In figure 8 we show how the low tide area is characterised by large sand waves, while at high tide (Figure 13) the presence of algal mats modify the chemical nature of the surface and subsurface sediment by changing the Eh and pH of the interstitial water. The shear strength profiles in figure 11 and the moisture release curves shown in figure 12 provide additional information that can also only be provided by field or laboratory investigation. In contrast, the ripples at the sediment surface illustrated in figures 9 and 10, together with the anaerobic sediment lying just below an algal mat shown figure 14 are observable on the shore by direct observation.

The biological patterns caused by the activities of microorganisms and animals in and on the sediment are usually more immediately obvious, unless they are microscopic. However the secretions produced by many burrowing invertebrates that bind sediment particles in their burrow linings, thus increasing the strength of the lining, can only be seen easily by scanning electron microscopy. We illustrate these in figure 15. The burrows themselves can usually be observed by digging into the sediment, or seen at the surface as burrow openings (Figures 17 to 25). On Ardmore Bay, the two dominant species in this context are the mud burrowing shrimp, *Corophium volutator*, and the lugworm *Arenicola marina*. Both are major bioturbators, moving large quantities of sediment during the construction and maintenance of their burrow systems. The burrows of both species can be observed by digging (Figures 17, 18, 21), and their openings are obvious on the sediment surface (Figures 4, 5, 19, 20, 23, 24, 25). Many smaller invertebrates can also leave tracks at or near the sediment surface. One such is illustrated in figure 27 and another in figure 30. Movement of seaweeds by tidal flow just as the tide leaves the sediment surface often also produce recognisable drag marks (Figure 27).

Fish and birds can cause major disturbance at the sediment surface or deposit material there. The regurgitated shell fragments of bivalve molluscs eaten by birds are very obvious when present (Figure 28). Gulls and ducks leave footprints, and they or fish may produce long tracks on the sediment that are very obvious even from a distance (Figure 30).

All of the above indicates that the intertidal sedimentary ecosystem is a dynamic one. Ardmore Bay is just one example of many such ecosystems where interactions between the physical and chemical properties of sediments and their living organisms produce a complex mix of processes. The effects of many of these processes can be seen within the sediment and at the sediment surface by direct observation on most intertidal muddy sand beaches.

ACKNOWLEDGEMENTS

The laboratory experiments shown in figures 12, 20 and 21, were conducted by Dr Naureen Qureshi while holding an Association of Commonwealth Universities (ACU) postdoctoral fellowship with Azra Meadows and Peter Meadows. This work was conducted jointly with Hugh Flowers.

REFERENCES

Armitage, A.R. & Fong, P. 2006. Predation and physical disturbance by crabs reduce the relative impacts of nutrients in a tidal mudflat. Marine Ecology-Progress Series 313, 205-213.

Black, K.S., Paterson, D.M. & Cramp, A. (editors) 1998. *Sedimentary Processes in the Intertidal Zone*. Geological Society of London, Bath.

Cadée, G.C. (1976) Sediment reworking by *Arenicola marina* on tidal flats in the Dutch Wadden Sea. *Netherlands Journal of Sea Research* 10, 440–460

Cadée, G.C. (1979) Sediment reworking by the polychaete *Heteromastus filiformis* on a tidal flat in the Dutch Wadden Sea. *Netherlands Journal of Sea Research* 13, 441–456

Cadée, G.C. 1990. Feeding traces and bioturbation by birds on a tidal flat, Dutch Wadden Sea. *Ichnos*.1, 23-30.

Cadée, G.C., Guang, M.H., Can, W.B., 1994. Animal traces on a tidal flat in Hangzhou Bay, China.
Netherlands Journal of Sea Research 32, , 73-80.

Carney, R.S. 1981. Bioturbation and biodeposition. Pp.357-445 in Boucot, A.J. (editor), *Principles of Benthic Marine Paleoecology*. Academic Press, New York.

Carrasco, N., Meadows, A. & Meadows, P. 2002. Community structure and biometrics in microhabitats within mussel beds (*Mytilus edulis*) from intertidal environments at Ardomore Bay, Clyde Estuary, Scotland. *The Glasgow Naturalist* 24, 23-28

Consalvey, M., Paterson, D.M. & Underwood, G.J.C. 2004. The ups and downs of life in a benthic biofilm: Migration of benthic diatoms. *Diatom Research* 19, 181-202.

Consalvey, M., Perkins, R.G., Paterson, D.M. & Underwood, G.J.C. 2005. Pam fluorescence: A beginners guide for benthic diatomists. *Diatom Research* 20, 1-22.
Deloffre, J., Lafite, R., Lesueur, P., Lesourd, S., Verney, R., & Guezennec, L. 2005. Sedimentary processes on an intertidal mudflat in the upper macrotidal Seine estuary, France. *Estuarine Coastal and Shelf Science*, 64, 71-720.
Fog M. 1967. An investigation on the Brent Goose (*Branta bernicla*) in Denmark. *Danish Review of Game Biology* 5, 3–40.
Frostick, L.E. & McCave, I.N. 1979. Seasonal shifts of sediment within an estuary mediated by algal growth. *Estuarine and Coastal Marine Science* 9, 569-576.
Grant J (1983) The relative magnitude of biological and physical sediment reworking in an intertidal community. *Journal of Marine Research* 41, 73–689
Haines, W.B. 1930. The hysteresis effect in capillary properties and the modes of moisture distribution associated therewith. *Journal of Agricultural Science*. 20, 96–105.
Horn, M.H., Martin, K.L.M. & Chotkowski, M.A. (editors). 1999. *Intertidal Fishes*. Academic Press, San Diego.
Iribarne, O., Bruschetti, M., Escapa, M., Bava, J., Botto, F., Gutierrez, J., Palomo, G., Delhey, K., Petracci, P., & Gagliardini A. 2005. Small- and large-scale effect of the SW Atlantic burrowing crab Chasmagnathus granulatus on habitat use by migratory shorebirds. *Journal of Experimental Marine Biology and Ecology* 315, 87-101.
Jickells, T.D. & Rae, J.E. (editors) 1997. *Biogeochemistry of intertidal sediments*. Cambridge University Press, Cambridge.
Little, C. & Kitching, J.A. 1996. *The Biology of Rocky Shores*. Oxford University Press, Oxford.
Madsen J. 1988. Autumn feeding ecology of herbivorous wildfowl in the Danish Wadden Sea, and impact of food supplies and shooting on movements. *Danish Review of Game Biology* 13, 1–32.
Mathieson, A.C. & Nienhuis, P.H. (editors). 1991. *Intertidal and littoral ecosystems*. Elsevier, Amsterdam.
Meadows P.S. & Campbell, J.I. 1988. *Marine Science. An Introduction* 2nd edt. Blackie, Glasgow.
Meadows, P. S. & Tait, J. 1985.Bioturbation, geotechnics and microbiology at the sediment-water interface in deep-sea sediments. Pp. 191-199 in Gibbs, P.E. *Proceedings of the Nineteenth European Marine Biology Symposium*. Cambridge University Press, Cambridge.
Meadows, P. S. & Tait, J. 1989. Modification of sediment permeability and shear strength by two burrowing invertebrates. *Marine Biology* 101, 75-82.
Meadows, P. S., Tait, J. & Hussain, S. H. 1990. Effects of estuarine infauna on sediment stability and particle sedimentation. *Hydrobiologia* 190, 263-266.
Meadows, A., Meadows, P. S., Muir Wood, D. & Murray, J. M. H. 1994. Microbiological effects on slope stability: an experimental analysis. *Sedimentology* 41, 423-435.
Meadows, P. S., Meadows, A., West, F. J. C., Shand, P., & Shaikh, M. A. 1998a. Mussels and mussel beds (Mytilus edulis) as stabilisers of sedimentary environments in the intertidal zone. Pp. 331-347 in Black, K.S., Paterson, D.M. & Cramp, A. (editors) *Sedimentary Processes in the Intertidal Zone*, Special Publications 139, Geological Society, London.
Meadows, P. S., Murray, J. M. H., Meadows, A., Muir Wood, D., & West, F. J. C. 1998b. Microscale biogeotechnical differences in intertidal ecosystems. Pp. 349-366 in Black, K.S., Paterson, D.M. & Cramp, A. (editors) *Sedimentary Processes in the Intertidal Zone*, Special Publications 139, Geological Society, London.
Meadows, P. S. & Hariri, M. S. B. 1991. Effects of two infaunal polychaetes on sediment shear strength and permeability: an experimental approach. *Symposium of the Zoological Society of London*, 63, 319-321.
Meadows, A., Meadows, P.S., & Mclaughlin, P. 1998c. Spatial heterogeneity in an intertidal sedimentary environment and its macrobenthic community. Pp. 367-388 in Black, K.S., Paterson, D.M. & Cramp, A. (editors) *Sedimentary Processes in the Intertidal Zone*, Special Publications 139, Geological Society, London. Meadows, P.S., Tait, J. & Hussain, S.H. 1990. Effects of estuarine infauna on sediment stability and particle sedimentation. *Hydrobiologia*, 190, 263-266.
Meadows, P.S. & Shand, P. 1989. Experimental analysis of byssus thread production by *Mytilus edulis* and *Modiolus modiolus* in sediments. *Marine Biology* 101, 219-226.
Meadows, P.S. & Tufail, A. 1986. Bioturbation, microbial activity and sediment properties in an estuarine ecosystem. *Proceedings of the Royal Society of Edinburgh*. Series B: 90, 129-142.Muir Wood, D., Meadows, P. S. & Tufail, A. 1990. Biological strengthening of marine sediments. Pp. 306-316, in Howsam, P. (editor) *Microbiology in Civil Engineering* FEMS Symposia 59 Chapman and Hall, London.
Muir Wood, D., Meadows, A., Murray, J.M.H. & Meadows, P.S. 1995. Effect of fungal and bacterial colonies on slope stability. Pp 46-51. in Barker, D.H. (editor.) *Vegetation and Slopes - Stabilisation, Protection and Ecology*. International Conference. Institution of Civil Engineers. Oxford. Thomas Telford, London.
Murray, J.M.H., Meadows, A. & Meadows, P.S. 2002. Biogeomorphological implications of microscale interactions between sediment geotechnics and marine benthos: a review. *Geomorphology* 42, 15-30.
Newell, R.C. 1979. *Biology of Intertidal Animals*. 3rd Edt. Faversham : Marine Ecological Surveys Ltd.
Olafsson, J.S. & Paterson, D.M. 2004. Alteration of biogenic structure and physical properties by tube-building chironomid larvae in cohesive sediments. *Aquatic Ecology* 38, 219-229.
Orvain, F. Sauriau, P.G., Bacher, U. & Prineau, M. 2006. The influence of sediment cohesiveness on bioturbation effects due to Hydrobia ulvae on the initial erosion of intertidal sediments: A study combining flume and model approaches. *Journal of Sea Research* 55, 54-73.
Paarlberg, A.J., Knaapen, M.A.F., de Vries, M.B., Hulscher, S.J.M.H. & Wang, Z.B. 2005. Biological influences on morphology and bed composition of an intertidal flat. *Estuarine Coastal and Shelf Science* 64, 577-590.
Reichelt, A.C. 1991. Environmental effects of meiofaunaal burrowing. Pp.33-52 in Meadows, P.S. & Meadows, A. (editor). *The Environmental Impact of Burrowing Animals and Animal Burrows*. Zoological Society of London Symposium, vol. 63. Clarendon Press, Oxford.
Reise K (1985) *Tidal Flat Ecology*. (Ecological studies, vol 54). Springer, Berlin Heidelberg New York.
Roast, S.D., Widdows, J., Pope, N. & Jones, M.B. 2004. Sediment-biota interactions: mysid feeding activity enhances water turbidity and sediment erodability. *Marine_Ecology-Progress Series* 281, 145-154 .
Shaikh, M.A., Meadows, A. & Meadows, P.S. 1998. Biological control of avalanching and slope stability in the intertidal zone. Pp. 309-329 in Black, K.S., Paterson, D.M. & Cramp, A. (editors) *Sedimentary Processes in the Intertidal Zone*, Special Publications 13, Geological Society, London.

Siebert, T. & Branch, G.M. 2006. Ecosystem engineers: Interactions between eelgrass *Zostera capensis* and the sandprawn *Callianassa kraussi* and their indirect effects on the mudprawn *Upogebia Africana. Journal of Experimental Marine Biology and Ecology* 338, 253-270.

Thiel, H. 1981. Aviturbation – eine Hypothese oder die Ramsar Konvention von 1971 zum Schutze der menschlichen *Umwelt. Seevögel* 2, 69–74.

Tufail, A. 1985. Microbial aggregates on sand grains in enrichment media. *Botanica Marina* 28, 209-211.

Tufail, A., Meadows, P. S. & Mclaughlin, P. 1989. Meso- and micro-scale heterogeneity in benthic community structure and the sedimentary environment on an intertidal muddy-sand beach. Proc. 22nd European Marine Biological Symposium, Barcelona. *Scientia Marina* 53, 319-327.

Tyler-Walters, H., 2006. *Arenicola marina*. Blow lug. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom.. Available from: <http://www.marlin.ac.uk/species/Arenicolamarina.htm>

Wells, G.P., 1945. The mode of life of *Arenicola marina* L. *Journal of the Marine Biological Association of the United Kingdom*, **26**, 170-207.

Widdows, J., Brown, S., Brinsley, M.D., Salkeld, P.N. & Elliott, M. 2000. Temporal changes in intertidal sediment erodability: influence of biological and climatic factors. *Continental Shelf Research* 20, 1275-1289.

Zonfrillo, B. 2004, 2007. Personal communication.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 109-111.

CALLITRICHE PALUSTRIS L. IN THE ENDRICK VALLEY

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 0DX

ABSTRACT
The discovery of *Callitriche palustris* L. at Wards Ponds on Loch Lomondside in August 2000 confirmed the plant's status as a British plant. From a further examination of the site in 2005, field characters observed in the terrestrial form of *C. palustris* are given, together with a short list of its closest associates. Additional survey work revealed that *C. palustris* also occurred at several other locations in the district.

INTRODUCTION
Although *Callitriche palustris* L. had found its way into several published accounts, until very recently the inclusion of this little known water-starwort on the British List lacked confirmatory evidence. The question of status was finally resolved when – just a year after the species had been reliably reported from the west of Ireland in 1999 – its presence in Britain was established. On 9 August 2000, Mr Richard Lansdown and Dr. Nigel Willby found *C. palustris* to be not uncommon in shallow water and on the drawn-down muddy fringe to Wards Ponds NS 445879, former haugh-land which had been embanked and drained in the 19th century for the growing of arable crops, but has since been abandoned and allowed to re-flood (N. Willby *pers comm.*; Watsonia (2003), 24(3): 392). Part of the Loch Lomond National Nature Reserve, Wards Ponds are on the Dunbartonshire (Vc. 99) side of the lower reaches of the River Endrick.

With the succession of generally wet summers in the west of Scotland that followed the event, it was 2005 before the conditions for close investigation of the Wards site were as favourable again. An almost continuous spell of exceptionally low rainfall and falling water levels beginning in mid-June gave the present author the opportunity of becoming acquainted with *C. palustris* which appeared in good numbers on the exposed mud. Notes provided by Dr. Willby, together with a published article that included a guide to the identification of the species by its fruits (Landsdown & Bruinsma, 1999), proved particularly helpful.

FIELD CHARACTERS AND ASSOCIATED SPECIES
The following field characters were observed in the terrestrial form of *Callitriche palustris*:

Small and low-growing in common with the other species of water-starwort present on the drying-out mud. Young specimens of *C. palustris* initially very compact, superficially having the appearance of a condensed spider's web, before the individual stems elongate as they spread outwards. Leaves greyish-green, becoming lemony-green with age, at which stage the plants show a tendency to die out from the centre. When fully expanded, the leaves of each stem's terminal rosette elliptical to sub-rhomboid (not spathulate as *Callitriche hamulata* or broadly round as *C. stagnalis*). All leaves with un-notched tips. Fruits – present in every mature specimen examined – the most reliable aid to the identification of the species in the field. These are heart shaped, first greenish-white, turning steel-grey and finally black.

The most frequent associates of *Callitriche palustris* recorded at Wards Ponds were *C. hamulata*, *C. stagnalis, Lythrum portula* and *Gnaphalium uliginosum*, with occasional *Elatine hydropiper* and *Eleocharis acicularis*.

FURTHER SURVEY WORK IN THE AREA
With the possibility that there could be other localities for *C. palustris* in the surrounding area, a check was first made of the sandy shores around the south-east corner of Loch Lomond which also falls within the National Nature Reserve. Although occurring only sparingly, the species was met with again in a lagoon NS 433887 on the Ring Point, and on crossing the mouth of the River Endrick into Stirlingshire (Vc. 86), along the drawn-down edge NS 426901 to Crom Mhin Bay, both situations affording the plants shelter from wave action at summer loch levels. The same associated species were present as previously noted at Wards Ponds. With the onset of the more usual rainfall pattern from mid August, all three of the sites for *C. palustris* on the reserve were not long in being affected by rising water levels, leading to the low-lying ground being re-submerged.

By then the search for suitable spots for the plant had been extended to higher up the Endrick Valley. The first location prospected was Drymen Show Field, an area of flood plain with a history of constant shifts in the course of the river. Here *C. palustris*, along with its commoner associates, had colonized water-deposited silt building up around the yet to be completely sealed ends of a developing ox-bow lake NS 468876. Encircled by the ox-bow, the outline of an ancient river channel – now reduced to a rush-infested and occasionally water-filled hollow – provided an additional niche for the species (Fig. 1). Further upriver at Ballochcruin Haughs (Fig. 2), *C. palustris* turned up again in small quantity along the western edge of a shallow pool NS 523882, a semi-permanent feature that has only formed in the last ten years or so through a breakdown in the field drainage system. With its water sometimes

drying-up completely during sustained dry weather, the pool supported no other aquatic vegetation except for a few plants of *C. stagnalis* and *Veronica beccabunga*.

ACKNOWLEDGEMENTS
I am grateful to Richard Lansdown (BSBI referee for *Callitrichaceae)* for the verification of specimens of *Callitriche palustris* collected in the Endrick Valley. Normal Tait kindly prepared the author's photographs of the species and its habitat for publication.

REFERENCE
Lansdown, R.V. & Bruinsma, J. (1999). *Callitriche palustris* L: New for Britain and Ireland. *BSBI News* 82, 18-19.

Figure 1. *Callitriche palustris* on dried out and cattle trampled mud Drymen Show Field, 20/9/2005.

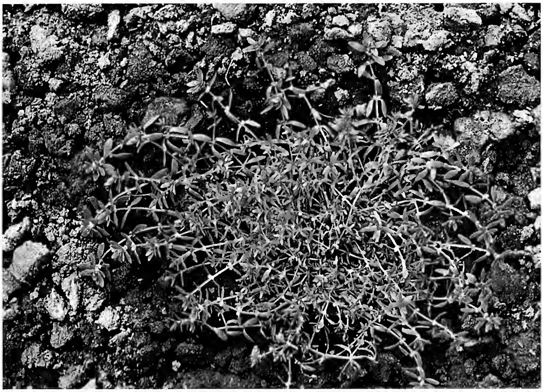


Figure 2. A shallow pool at Ballochcruin Haughs in the Endrick Valley, 16/9/2005 – a site for *Callitriche palustri.*

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 113-117.

LOCH LOMONDSIDE DEPICTED AND DESCRIBED
6. EARLY LANDSCAPE ARTISTS AND PHOTOGRAPHERS

John Mitchell
22 Muirpark Way, Drymen, Glasgow G63 0DX

"Most historians have had little concern for art as evidence"
John Morrison (2003) *Painting the Nation.* Edinburgh University Press.

ABSTRACT
The concluding part to a series of six articles highlighting just some of the early historians, geologists, geographers, naturalists and others who have left us a written or pictorial record of Loch Lomond and surrounds from times past. In this final paper attention is drawn to the first landscape artists and photographers to be attracted to the natural beauty of this part of Scotland, with examples given of their contribution towards our understanding of how the face of the region has changed over the years.

INTRODUCTION
A very cautious approach is required before accepting any early landscape sketch or painting as portraying a reasonably accurate representation of the chosen scene. Woodland historians have on occasions taken this step, showing that the less romanticised or impressionistic landscape studies can be a source of material on which to make a qualified judgement as to the extent of the tree cover, or in identifying major changes which have since taken place. Such pictures have proved particularly useful where maps and documentary sources for a given area or period are few or entirely lacking. It is against a background of renewed interest in yesteryear's landscape sketches or paintings and the stories they may have to tell, attention is drawn to just some of the people who captured on paper or canvas the face of Loch Lomondside as they saw it at different moments in time.
Perhaps not surprising considering the nation's turbulent past, two of the earliest artists known to have visited this part of the west of Scotland – John Slezer (f.1671-1717) and Francis Place (1647-1728) - confined their attention to Dumbarton Castle standing guard over the entrance to the River Leven, the link between Loch Lomond and the Clyde Estuary. The next generation of artists who came to a more peaceable country were able to venture further from the security of the town and castle, bringing Loch Lomondside's scenic beauty to the notice of the public for the very first time. In the mid 1800s they were joined in their endeavours by the first landscape photographers, after the practical difficulties of handling this new medium out of doors had been resolved.
This paper takes the form of brief biographies of twelve leading artists and photographers who bequeathed us a legacy of their Loch Lomondside work.

THE ARTISTS AND PHOTOGRAPHERS
Paul Sandby (1725-1809)
At the age of sixteen Paul Sandby from Nottingham joined the Board of Ordnance drawing room at the Tower of London. In the wake of the Jacobite uprising of 1745/46 he came north to Edinburgh to work as a draughtsman on William Roy's military map of the Scottish Highlands, his duties occasionally involving sketching alongside the field survey teams. It was probably in this latter capacity that he visited Dumbarton Castle and Loch Lomondside around 1750/51. Sandby's private drawings undertaken during his service in Scotland were not made generally available until the publication in 1781 of his *A Collection of One Hundred and Fifty Select Views in England, Scotland and Ireland.* Volume two contains several engravings of Loch Lomondside, including one of the banks of the River Leven on the eve of industrial development, which was to alter for ever what Sandby conveyed as an essentially rural scene.
Joseph Farington (1747-1821)
Joseph Farington from Leigh in Lancashire first came to wide attention with his engraved views of the English Lake District. His detailed diaries confirm that he also came north of the border on sketching tours, in 1788 and again four years later in 1792. Farington's 1788 portfolio of drawings was intended as a contribution towards a proposed major work depicting the scenery of Scotland, but with the death of the project's promoter the plan was abandoned. One of the water colours undertaken for the above publication - 'View of Dumbarton from the Castle' - shows that before embankments were constructed alongside the lower reaches of the Leven, the town meadows would be almost completely flooded at high tide. During his two visits to the region, Farington made sketches from several places around the southern half of the loch, in the process establishing some of the best viewing points such as Mount Misery (an old name for the highest eminence on Boturich estate) and Strone Hill overlooking the village of Luss, prime locations where later artists were to follow his lead.
George Garrard (1760-1826)
Noted particularly for his animal paintings, George Garrard was engaged in 1786 or thereabouts to accompany the noted field sportsman Colonel Thomas Thornton on a summer tour of North Britain, in order to set down on paper the scenes of his patron's exploits with rod and gun. Only one of several Loch Lomond sketches made by Garrard subsequently appeared in the Colonel's *A Sporting Tour etc.* published in 1804 - that of a Mallard *Anas*

platyrhynchos being brought down in flight by Thornton using his fowling piece from a boat positioned just off the shores of Inchmurrin. Despite his best efforts, Colonel Thornton failed to get within gunshot range of a pair of Ospreys *Pandion haliaetus* nesting on the ruins of Inchgalbraith Castle, so that the untimely end of the birds is one subject which Garrard was not called upon to record.

Alexander Nasmyth (1758-1840)

Born into a family of Edinburgh master-builders, Alexander Nasmyth's initial connection with Loch Lomondside came through his great grandfather, who was said to have been involved in an early unsuccessful attempt to establish a permanent military garrison at Inversnaid for the purpose of curbing the lawless activities of Clan Macgregor. A vignette of the eventually completed fortification in its mountainous setting drawn by Nasmyth was later used to illustrate the 1825 edition of Sir Walter Scott's novels and tales. The first of several local paintings produced by Nasmyth – 'View of the Banks of Loch Lomond' - was exhibited in 1808, his style aptly described as a blend of history and nature. Alexander Nasmyth had a feel for ancient woodland with an artistic eye for preserving the most venerable trees, something he was able to put to good use in another role as a consultant in the design of country estates.

Joseph Mallord William Turner (1775-1851)

London-born Joseph Turner came twice to Loch Lomondside – first in 1801 under the directions of his fellow academician Joseph Farington, and then thirty years later in 1831, principally at the invitation of Sir Walter Scott. Turner's itineraries for both years can still be traced from his surviving sketch books. On the first occasion he travelled from Dumbarton to Tarbet, and on his second trip from Inversnaid to Dumbarton when he almost certainly took advantage of the paddle steamer service then only recently introduced to the loch. A few of his sketches made at the time were worked-up into engraved illustrations for various publications, including those by Scott. Turner is also known to have produced three, possibly four water colours from his visits to Loch Lomondside, unfortunately all but one now lost to public view.

John Knox (1778-1845)

A native of Paisley, John Knox is believed to have studied under Scotland's leading landscape artist Alexander Nasmyth. Although Knox began his career as a portrait painter, he was regularly showing Loch Lomondside scenes in oils from 1821. The preliminary sketches for his acclaimed panoramic views from Ben Lomond's summit, with the loch and its islands stretched out below, were probably made with the aid of a portable camera obscura. The two large canvases – exhibited as a pair for the first time in 1834 – have been widely reproduced, including being used as publicity material for the Loch Lomond Regional Park after it was set up in 1988.

George Fennel Robson (1788-1833)

George Fennel Robson from County Durham showed a talent for drawing from a very early age by copying woodcuts from Thomas Bewick's *General History of Quadrupeds* first published in 1790. Although he was quite prepared to produce work in the picturesque manner which book publishers of the day seemed to prefer, for his own privately printed *Scenery of the Grampian Mountains* (1814 & 1819) Robson demonstrated a more draughtsman-like style. Of additional interest are the natural history notes scattered throughout the publication's text. Four Loch Lomond scenes are included in this work. His view south from an elevated position in Glen Falloch (Fig. 1), illustrates clearly just how fragmented the native woodland at the head of the loch had become by the turn of the 19th century.

John Fleming (1792-1845)

John Fleming is usually associated with the Inverclyde town of Greenock, but according to his obituarist he was born in Glasgow. Though an established portrait painter, Fleming is undoubtedly best known today as having been an illustrator of topographical books published by the Glasgow engraver Joseph Swan, including John Leighton's *The Lakes of Scotland* which was first issued in parts from 1830. In this work he contributed the frontispiece and three plates of Loch Lomondside, one of these the island-strewn lake as seen from Mount Misery (Fig. 2). The foreground to Fleming's picture shows this part of the district in an open unimproved state, before the sweeping changes which were about to take place with the introduction of new farming and forestry practices.

Horatio McCulloch (1805-1867)

Another Glasgow man, Horatio McCulloch, was briefly a pupil of the foremost Scottish landscape artist at the time, John Knox. His first employment was decorating snuff boxes, miniature work that was a far cry from the large oil paintings for which he was later to achieve fame. Other early work included adding water colours to engraved prints of P.J. Selby's *Illustrations of British Ornithology* issued in parts between 1821 and 1834. As a landscape painter, from 1830 onwards a dozen or more of his Loch Lomondside studies can be identified from exhibition catalogues and art reviews. Best known of these today is a view northwards from that old favourite, Mount Misery, the most widely reproduced version of this scene completed in 1861. However, the rough countryside that McCulloch portrays in the foreground to this particular picture had by then been overtaken by laid-out plantations and enclosed fields (ref. the first edition of the six inch Ordnance Survey map of Dunbartonshire c.1860), a timely reminder of the potential pitfalls in interpreting a painting too literally where the artist has deliberately harked back to an earlier period in order to create a more dramatic or pleasing effect.

Unlike the artists who had gone before him, Horatio McCulloch would have been very much aware of the appearance in the Scottish countryside of the first landscape photographers, having almost certainly come across what he possibly saw as competitors setting-up their cumbersome equipment in the best viewing spots. William

Henry Fox Talbot (1800-1877) – who perfected and patented the Calotype process, whereby any number of prints could be obtained from just one sensitised paper negative – was first into the south-west Highlands when he came up from Wiltshire to Loch Katrine and the Trossachs in the autumn of 1844 to take his innovative 'Sun Pictures' . Regrettably, Talbot seems not to have travelled those extra few miles to direct his lens at Loch Lomond. By the mid 1850s, the Calotype had been overtaken by the development of the Collodion or wet-plate process, the negatives preserved on glass instead of paper.

George Washington Wilson (1823-1893)

George Washington Wilson from Banffshire originally trained as a portrait miniaturist, in 1849 establishing himself as a professional artist in Aberdeen. By 1853 however, Wilson had added the taking of photographic portraits to his business interests. Changing direction he was soon at the forefront of landscape photography, being awarded the title 'Photographer to the Queen' for his commissioned studies of Balmoral on Royal Deeside. By the late 1850s he had entered the popular field, making repeated expeditions to all the tourist hot-spots in Scotland in the quest for new pictures of by now familiar scenes. Even before the advent of the cheap picture post card, Wilson's scenic photographs sold in their thousands, his company eventually offering at least 100 different views of Loch Lomondside to meet the demand for souvenirs of a holiday visit. Looking beyond the Rowardennan Inn in the example given of Washington Wilson's high quality work (Fig. 3), there caught by the camera is a stand of ancient Scots Pine *Pinus sylvestris* at the foot of Ben Lomond. According to naturalist John A. Harvie Brown writing in the journal *Zoologist* of 1867, this relic pine wood was the last nesting place of the Red Kite *Milvus milvus* in Stirlingshire. Housed at the University of Aberdeen, the Wilson collection of over 40,000 glass negatives is a treasure trove as a historical resource.

James Valentine (1815-1879)

As a young man James Valentine also began his career by studying portrait painting, but at the age of seventeen he was summoned home to Dundee to work in the family business as an engraver of pattern blocks for textile printing. By 1840 he had set-up for himself as an engraver and stationer, eleven years later advertising studio photography to his range of services on offer. Seeking to emulate the commercial success of George Washington Wilson's topographical pictures, he branched out into landscape photography in the early 1860s. So closely did he adhere to Wilson's summer itinerary for his material, it was jokingly said at the time that Valentine scoured Scotland seeking the holes left in the ground by his competitor's tripod. In 1878 when the firm was reorganised in favour of his sons, the Valentine catalogue listed over 40 views of Loch Lomondside. Amongst these is an attractive study of traditional thatched cottages at Tarbet (Fig. 4), but of considerably more interest to the woodland historian is the background to the photograph – a view of the Craigrostan oak woodlands at a time when the Montrose Estate records confirm that they were still managed for the production of tan bark. Although when seen from this distance some areas of the lower hillside appear denuded of trees, the slopes were in fact clothed with cut oak stools (stumps) throwing up fresh coppice growth. A substantial archive of Valentine photographs – including his Loch Lomondside pictures - was donated to the University of St. Andrews where it is available for consultation.

Thomas Annan (1829/30-1887)

Thomas Annan moved from Fife to Glasgow in 1849, taking up employment with the engraving and publishing firm of Joseph Swan. By 1855 he had opened his own photographic studio, becoming highly skilled in portraiture and in producing facsimiles of works of art. However, it was in the recording of old Glasgow's narrow streets and crowded together buildings about to be lost to large-scale redevelopment that was to make his name. Although Annan won the medal awarded by the Photographic Society of Scotland for the best landscape study submitted in 1865, compared to both Wilson and Valentine he made comparatively few of his scenic views commercially available, apparently having little enthusiasm for furthering the tourist-led image of Scotland as a wild, untamed land of mountain and flood. Amongst Annan's photographs used to illustrate the building of the dams and pipeline for Glasgow's Loch Katrine Water Scheme are pictures of the Endrick and Blane Valleys – parts of Loch Lomondside well off the beaten track for most Victorian sightseers and in consequence ignored by his rival professional photographers. Regrettably, the fate of most of his landscape negatives is unknown.

ACKNOWLEDGEMENTS

My thanks to Mary Bruce for reading through and commenting on the first draft of this paper, and to Norman Tait for preparing the four illustrations for publication.

SELECTED BIOGRAPHICAL REFERENCES

Anon. (1845). John Fleming: Obituary. *Greenock Advertiser*, 28 March 1845.

Buchanan, G. (1972). *Scenic Aspects of the River Clyde* (exhibition catalogue). Glasgow Art Gallery & Museum.

Gray, J.M. (1909). 'Alexander Nasmyth (1758-1840)' in *Dictionary of National Biography* (2nd ed.), Vol. XIV, pp. 113-115. Smith & Elder, London.

Graves, R.E. (1908). 'George Garrard (1760-1826)' in *Dictionary of National Biography* (2nd ed.), Vol. VII, p. 890. Smith & Elder, London.

Holloway, J. & Errington, L. (1978). 'Paul Sandby and Scotland' in *The Discovery of Scotland*, pp. 32-46. H.M.S.O., Edinburgh.

Irwin, F. & Wilton, A. (1982). *Turner in Scotland* (exhibition catalogue). Aberdeen Art Gallery & Museum.

McClure, I. (1974). *John Knox: Landscape Painter* (exhibition catalogue). Glasgow Art Gallery & Museum.

Mackenzie, R. (1992). Thomas Annan and the Scottish Landscape. *History of Photography* 16, 40-49.
Monkhouse, C. (1909). 'George Fennel Robson (1788-1833)' in *Dictionary of National Biography* (2nd ed.). Vol. XVII, p. 61. Smith & Elder, London.
Sutton, C.W. (1908). 'Joseph Farington (1747-1821)' in *Dictionary of National Biography* (2nd ed.). Vol. VI, pp. 1071-1072. Smith & Elder, London.
Smart, R. (1988). "Famous Throughout the World": Valentine & Sons Ltd., Dundee. *Review of Scottish Culture* 4, 75-87.
Smith, S. (1988). *Horatio McCulloch 1805-1867* (exhibition catalogue). Glasgow Museums & Art Galleries.
Taylor, R. (1981). *George Washington Wilson: Artist and Photographer 1823-93*. University of Aberdeen.

Fig. 1. Glen Falloch looking south towards Ben Lomond (George Fennel Robson).

Fig. 2. Loch Lomond from Mount Misery (John Fleming).

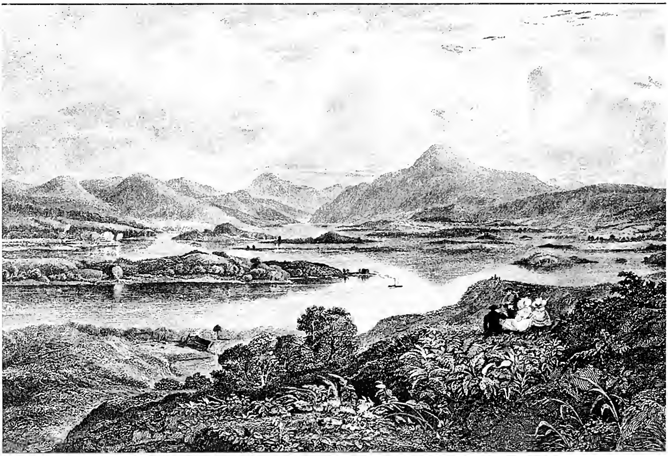
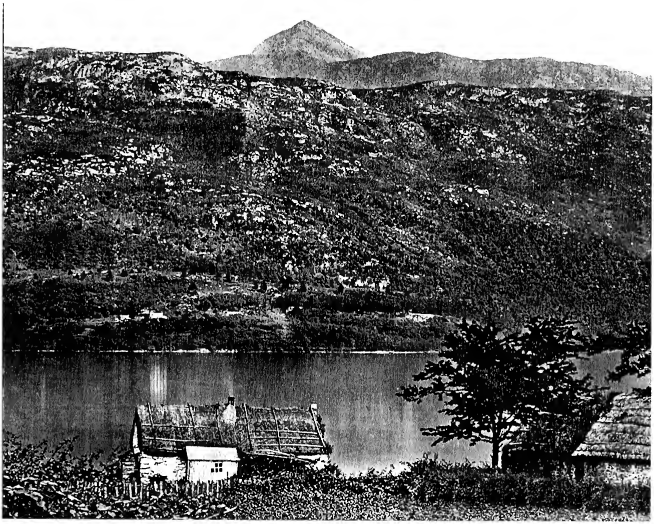


Fig. 3. The Rowardennan Inn and Ben Lomond (George Washington Wilson).

Fig. 4. Craigrostan and Ben Lomond from Tarbet (James Valentine).



Glasgow Naturalist 2006. Volume 24. Part 4. Pages 119-124.

NEW RECORDS OF TANTULOCARIDA, PARASITES OF MARINE CRUSTACEANS, FROM SCOTTISH WATERS.

Myles O'Reilly
Scottish Environment Protection Agency
Redwood Crescent
East Kilbride
G74 5PP
myles.oreilly@sepa.org.uk

ABSTRACT

The Tantulocarida is a small group of minute enigmatic parasitic crustaceans. They live as ectoparasites on other crustaceans such as copepods, ostracods, cumaceans, isopods, tanaids, or amphipods. They are relatively poorly known with only about 20 species described so far. Tantulocarids have mainly been found on deep water crustaceans, but they also occur in shallow waters. Three species have been described from deep waters of the Rockall Trough (2-3000m), which lie around 2-300km west of Scotland. The present paper highlights new records of three species from relatively shallow Scottish waters, collected during routine environmental monitoring surveys over a number of years. These species are *Microdajus langi* Greve, 1965, *Amphitantulus harpiniacheres* Boxshall & Vader, 1993, and probably *Cumoniscus kruppi* Bonnier 1903. Some additional new records from Belfast Lough and off the Northumberland coast are also noted.

INTRODUCTION

The Tantulocarida is a small group of minute enigmatic parasitic crustaceans. They live as ectoparasites on other crustaceans such as copepods, ostracods, cumaceans, isopods, tanaids, or amphipods. They are relatively poorly known with only about 20 species described so far. Although first observed over 100 years ago, most have been discovered in recent years. They were originally regarded as aberrant parasitic isopods or copepods but their status as a distinct class of crustacean was recognised around 20 years ago (Boxshall & Lincoln, 1983). They have a most unusual complex life cycle which has only recently been elucidated. This involves a parasitic phase which may involve asexual (parthenogenetic) reproduction, as well as dispersive phases of free swimming larvae or sexual males and females (Boxshall & Lincoln, 1987).

The tantulus larva is about 0.1mm long and comprises a shield shaped head and a six-segmented trunk with tiny legs and a short tail region. It adheres to its host with an anterior attachment disc and subsequently a large brood sac emerges from the larval trunk attaining a length of around 1mm. It is at this stage the tantulocarid is most conspicuous. Developing within the brood sac are either a single large sexual male or female or, in parthenogenetic females, numerous eggs which subsequently hatch into additional tantulus larvae (Huys, Boxshall, & Lincoln, 1993).

Most records of tantulocarids have been accidental finds of parasitic stages in the course of surveys of crustaceans. However, free swimming stages have occasionally been recovered as temporary members of the meiobenthos communities (Huys, Andersen & Kristensen 1992).

So far, tantulocarids have mainly been found on deep water crustaceans, but they do also occur in shallow waters. Three species have been described from deep waters of the Rockall Trough (2-3000m), which lie around 2-300km west of Scotland. Two of these were attached to tanaids, namely *Microdajus gaelicus* Boxshall & Lincoln, 1987 on *Typhlotanias pulcher* Hansen, and *Microdajus pectinatus* Boxshall, Huys & Lincoln,1989 on an undescribed *Typhlotanais sp.* The third species, *Deoterthron harrisoni* Boxshall & Lincoln,1987 was found on the isopod *Macrostylis magnifica* Wolff. Only a single species, *Microdajus langi* Greve, 1965 is so far known to occur in Scottish coastal waters where it parasitizes various species of tanaid.

The present paper highlights new records of three species from relatively shallow Scottish waters, collected during routine environmental monitoring surveys over a number of years. Some additional new records from Belfast Lough and off the Northumberland coast are also noted.

RESULTS

Microdajus langi Greve, 1965

1 parthenogenetic female and 3 tantulus larvae attached to the tanaid *Akanthophoreus gracilis* (Kroyer, 1842) collected 26th April 1989 at Bell Rock sewage disposal grounds (Stn.17, 56 °25.00'N, 02 °06.38'W, depth 64m), about 13km east of Bell Rock, Forth Sea Area. This material is deposited in the British Museum (NH), London.

1 parthenogenetic female, with developing eggs **(Figure 1)** attached to *Akanthophoreus gracilis* (Kroyer, 1842) collected 3rd August 2001 at South Shian (SEPA Stn. 4, 56 °31.274'N, 05°23.871'W, depth 7m), Loch Creran, West Scotland.

Deposited in National Museum of Scotland (NMSZ:2006.015.0001).

Microdajus langi is widely distributed in coastal waters. The original description by Greve, 1965 is from Raunefjorden, Norway at 120-130m depth on the taniads *Leptognathia breviremis* (Lilljeborg), and *Typhlotanias aequiremis*. It was recorded by Boxshall & Lincoln (1987) from Cumbrae, Firth of Clyde, on a juvenile tanaid, at 113m depth, and in the Lynn of Lorne, Loch Linnhe, on *Leptognathiopsis attenuata* Holdich & Bird at only

22m depth. Grygier & Seig (1988) observed it on *L. breviremis* from Gullmarfjord, Sweden, and Greve (1988) provided further records from Norway. The new scottish record from Loch Creran is close to the earlier find from Lynn of Lorne but on a different tanaid host and in even shallower water.

During preparation of this paper further specimens of *M.langi* were received for examination. These were all from *A.gracilis* and included a single tantulus larva, attached to the host gnathopod, collected from Belfast Lough (EHS Stn.F1, 54°42.19'N, 05°35.54'W, depth 24.4m). Five parasitized taniads were recovered from off the Northumberland coast in 2002 and 2003 at, or close to, Stn.M1(=Stn.27), approx. 55 °04.50'N, 01°15.00' W, depth 55m, Dove Marine Lab, Cullercoats, see Buchanan *et al.*1978). These comprised: i) 1 taniad with 3 tantulocarids - 2 with single developing sexual female in brood sac, and 1 parthenogenetic female, with developing tantulus larvae in brood sac, all attached dorsally; ii) 2 tanaids each with 1 parthenogenetic female tantulocarid attached dorsally with developing tantulus larvae in brood sac; and iii) 2 tanaids with 1 parthenogenetic female, attached at base of gnathopod, with numerous developing tantulus larvae in large brood sac, (latter shown in **Figure 2**). The Northumberland specimens are deposited in the National Museum of Scotland (NMSZ:2006.015.0002-4).

***Amphitantulus harpiniacheres* Boxshall & Vader, 1993**

7 tantulocarids which included 1 tantulus larva, and 6 with brood sacs all attached to a single juvenile amphipod, *Harpinia antennaria* Meinert,1890 **(Figure 3)** collected in February 2000 at 107m depth, 2.5km north of the Miller Platform (58 °44'N, 01 °24'E). The tantulocarids with brood sacs each have a single developing sexual adult curled up inside **(Figure 4)**. The number of pairs of developing legs discernable (around 6) indicates these are males, rather than sexual females, which only have 2 pairs.

However, the head shield and body trunk, with legs and tail, of the preceding larval stage are still evident **(Figure 5, 6)**. The amphipod *H. antennaria* may attain an adult length of around 5mm. The number of tantulocarid parasites on this juvenile, only about 1mm long, must represent a significant burden.

It is surprising that the existence of this species has been overlooked until quite recently. The host *H. antennaria* is widely distributed in relatively shallow coastal waters and frequently occurs in benthic monitoring surveys. The type description is from the MIME field, in the central northern North Sea, about 300km east of Aberdeen (but 5km inside the norwegian sector) at 80m depth. Boxshall & Vader observed 64 infested *H. antennaria* with a total of 216 tantulocarids. The new scottish material was collected about 200 km further north, and about 300km east of John O'Groats and just 5km inside the British (Scottish!) sector boundary. This appears to be the first record within british territorial waters. The parasitised amphipod is deposited in the National Museum of Scotland (NMSZ:2006.015.0005).

?*Cumoniscus kruppi* Bonnier 1903

1 tantulus larva with developing adult (male?) in brood sac attached to carapace of the cumacean *Diastylis lucifera* collected in the Minches, on the west coast of Scotland sometime in the late 1980s. The specimen was shown to the author by a colleague at a taxonomic workshop in 1990. Unfortunately the specimen was lost prior to a more detailed examination. The identification is tentative and based solely on the fact that *C. kruppi* is the only tantulocarid known to occur on a cumacean host. The record is mentioned here to alert benthic ecologists to its presence in Scottish waters in the hope that further specimens might come to light. However, over 660 *D.lucifera* collected from the St.Abbs disposal grounds in the Firth of Forth, between 1986 and 1989, have been examined by the author without any tantulocarids being observed.

C. kruppi was originally described from near the Isle of Capri in the Mediterrranean on an unidentified leuconid cumacean, collected at 1100m depth. A single specimen of this species was rediscovered in the Bay of Biscay at 307m depth, by Huys, Boxshall & Casanova (1993), attached to an apparently new genus of leuconid cumacean.

ACKNOWLEDGEMENTS

Acknowledgments are due to Kirsty Bauros (SEPA, East Kilbride), Tim Mackie (Environment & Heritage Service, Belfast), Tim Worsfold (Unicomarine, Letchworth), and Peter Garwood (Identichaet, Newcastle-upon-Tyne) for supplying tantulocarid material.

REFERENCES

Boxshall, G.A. & Lincoln, R.J.(1983). Tantulocarida, a new class of Crustacea ectoparasitic on other crustaceans. *Journal of Crustacean Biology* 3,1-16.

Boxshall, G.A. & Lincoln, R.J.(1987). The Life cycle of the Tantulocarida. *Philosophical Transactions of the Royal Society of London*, Ser.B 315, 267-303.

Boxshall, G.A., Huys, R., & Lincoln, R.J.(1989). A new species of *Microdajus* (Crustacea: Tantulocarida) parasitic on a tanaid in the northeastern Atlantic, with observations on *M.langi*. *Systematic Parasitology* 14, 17-30.

Boxshall, G.A., & Vader, W. (1993). A new genus of Tantulocarida (Crustacea) parasitic on an amphipod host from the North Sea. *Journal of Natural History* 27, 977-988.

Buchanan, J.B., Sheader, M. & Kingston, P.F. (1978). Sources of variability in the benthic macrofauna off the south Northumberland coast, 1971-1976. *Journal of the Marine Biological Association of the U.K.*, 58, 191-209.

Greve, L. (1965). A new epicaridean from western Norway parasitic on tanaidacea.
Sarsia 20, 15-19.

Greve, L. (1988). Litt om klassen Tantulocarida (Crustacea) – en gruppe orsma krepsdyrparasitter. *Fauna, Oslo* 41, 12-15.

Grygier, M.J., & Seig, J. (1988). *Microdajus* (Crustacea: Tantulocarida) parasitic on an Antarctic tanaid, and a range extension of *M. langi* Greve. *Journal of Natural History* 22, 1495-1505.
Huys, R., Andersen, P.F. & Kristensen, R.M. (1992). *Tantulacus hoegi* gen. et sp.nov. (Tantulocarida: Deoterthridae) from the meiobenthos of the Faroe Bank, North Atlantic. *Sarsia* 76, 287-297.
Huys, R., Boxshall, G.A., & Casanova, J-P. (1989). A redescription of *Cumoniscus* (Crustacea: Tantulocarida) from a cumacean host in the Bay of Biscay. *Systematic Parasitology* 26, 75-79.
Huys, R., Boxshall, G.A., & Lincoln, R.J. (1993). The Tantulid Life Cycle: The circle closed? *Journal of Crustacean Biology* 13(3), 432-442.

Figure 1 – Ventral view of tanaid, *Akanthophoreus gracilis,* from Loch Creran, with tantulocarid, *Microdajus langi,* attached behind the gnathopod, showing brood pouch, with developing parthenogentic eggs/larvae.

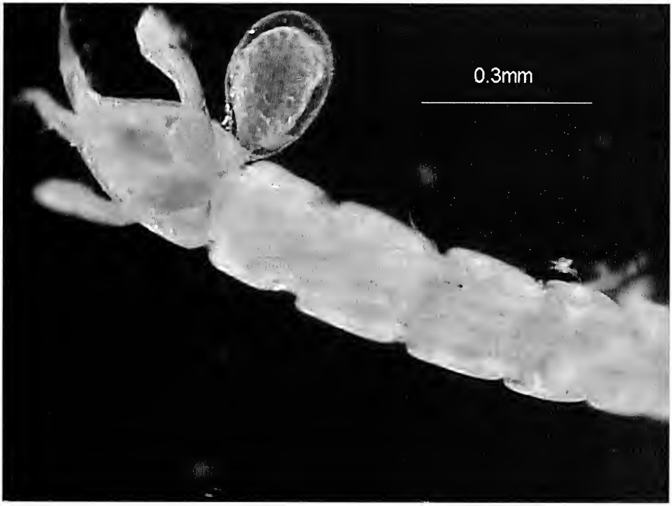


Figure 2 – Lateral view of tanaid, *Akanthophoreus gracilis,* from Northumberland coast, with tantulocarid, *Microdajus langi,* attached to base of the left gnathopod, showing brood pouch with developing parthenogenetic larvae.

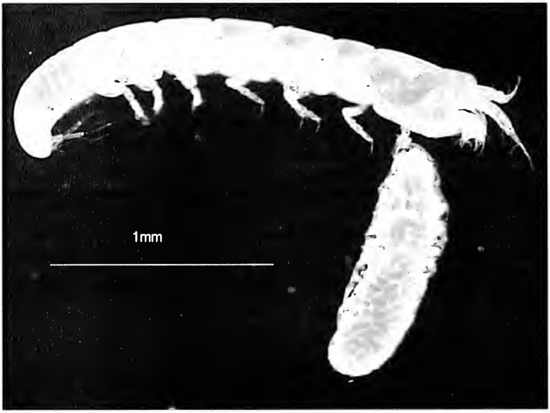


Figure 3 – Lateral left side view of juvenile amphipod, *Harpinia antennaria*, from the North Sea Miller Field, with five tantulocarids, *Amphitantulus harpiniacheres,* attached.

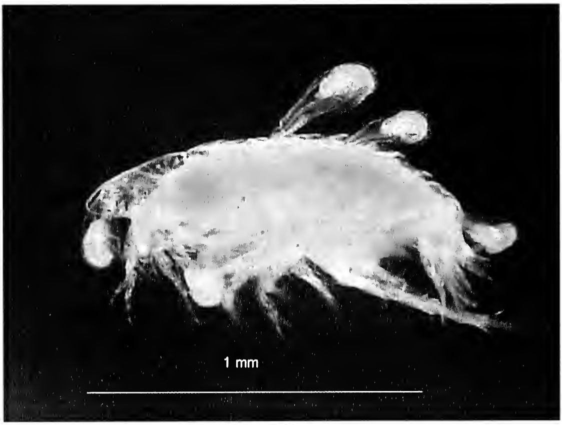


Figure 4 – Lateral view of tantulocarid, *Amphitantulus harpiniacheres* attached to amphipod, *Harpinia antennaria*. The head shield is to the left (above arrow tip). The segmented larval trunk is clearly visible with minute appendages on the lower side. The large brood sac extends posteriorly and within it the outline of a single developing sexual female stage can be seen, curled up with its legs tucked underneath its tail.

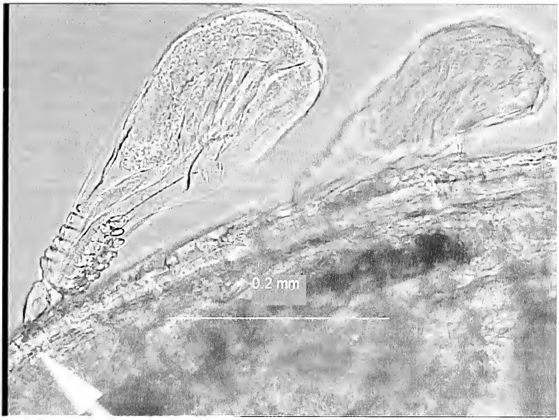


Figure 5 – Lateral view of tantulocarid, *Amphitantulus harpiniacheres* showing detail of the head shield (to the left) and the segmented larval trunk with minute legs and tail. An attachment thread can be seen running through the body to the brood sac containing a single developing sexual female.

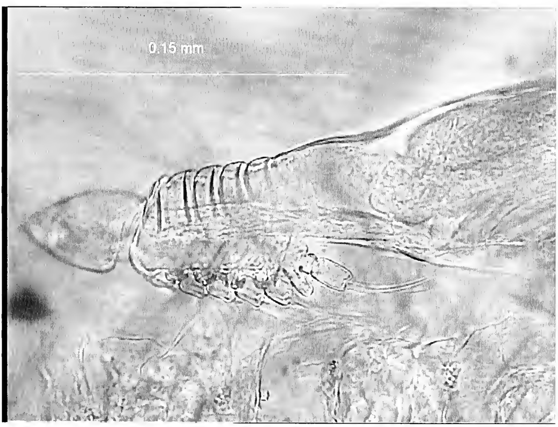
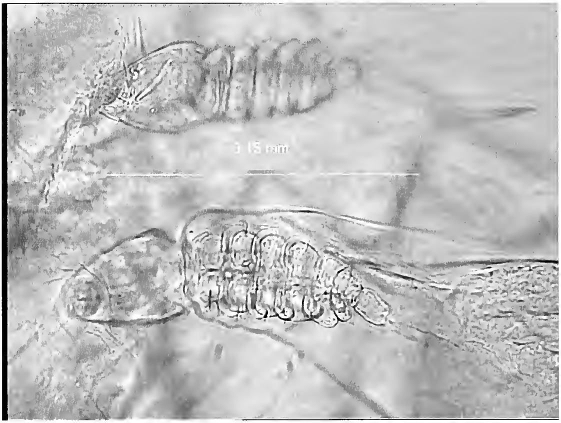


Figure 6 – Dorsal view of tantulocarid, *Amphitantulus harpiniacheres* showing the head shield (to the left) and the segmented larval trunk and tail. The larval trunk is visible through a transparent section of the brood pouch which extends posteriorly.



Glasgow Naturalist 2006. Volume 24. Part 4. Pages 125-153.

SCOTTISH ENTOMOLOGISTS' SURVEY ISLE OF RUM 2000

Peter Wormell (Editor)
Hallival, Letterwalton, Benderloch, Oban, Argyll, PA37 15A

Team Survey Recorders

C Allen	(CA)	Lepidoptera
Dr D Barbour	(DAB)	Lepidoptera
Dr K Bland	(KB)	Lepidoptera, Diptera, Hymenoptera, Odonata, Hemiptera
Dr D Beaumont	(DB)	Arachnida, Coleoptera
Dr S Blake	(SB)	Coleoptera (Carabidae)
Dr G Corbet	(GC)	Arachnida, Mollusca, Crustacea (Isopoda), Diplopoda (Millipedes), Chilopoda (Centipedes), Hemiptera, Neuroptera, Diptera, Hymenoptera
M Davidson	(MD)	Arachnida
Dr D Horsfield	(DH)	Diptera, Lepidoptera
Dr R & R Key	(RK)	Coleoptera, Odonata, Hymenoptera, Diptera
J MacKay	(JM)	Lepidoptera
Dr D Phillips	(DP)	Diptera (Tipulidae), Odonata, Orthoptera, Hymenoptera
Dr R C Welch	(RCW)	Coleoptera, Lepidoptera, Siphonaptera
P Wormell	(PW)	Lepidoptera, Hemiptera

When the Isle of Rum became a National Nature Reserve in 1957 the first Management Plan stipulated that a basic requirement for any nature reserve should be the production of catalogues of the flora and fauna. Much of our knowledge of plants and insects of the island at that time was gleaned from the publications of Professor J W Heslop Harrision who led regular expeditions to the island between 1934 and 1955. Doubts have been expressed over a number of his finds. Since he did not keep voucher specimens, his remaining records were placed in squared brackets in the island's master catalogue as requiring confirmation. During recent team surveys most of these old records have been confirmed, often from the exact localities in which he and his teams, comprising staff and students from Kings College, Newcastle Upon Tyne, found them.

Since 1960 the island has been subjected to fairly evenly-spaced bursts of entomological investigation. Teams of specialists, each concentrating on their own chosen order of insects or, in a few cases, several orders in a particular habitat, were brought together for up to two weeks at a time in an attempt to produce a reasonably comprehensive catalogue of the insect fauna. Only then would it be possible to accurately measure changes in invertebrate activity resulting from pastoral manipulation and woodland restoration. These have been the two main management activities aimed at restoring biodiversity.

Between 1960 and 1963 the island was visited by 10 entomologists at different seasons. During the four successive years covered by these initial surveys, in spite of the fact that it rained for almost half of the time, the field surveys produced a basic list of 1722 species of insects (Steel and Woodroffe, 1969). The team reconvened in August/September 1969 but the untimely death of Bill Steel on the last night of survey and that of his co-editor, Gerry Woodroffe, a few years later, meant that the collation of data from this gathering was a protracted process.

Records from these surveys, combined with those of visiting and resident entomologists, were, however, eventually brought together and published in 1982 (Wormell, 1982). By then, the number of confirmed species had risen to 2137.

During each of the team surveys new species were turning up and, as time went by, a fair assessment of the island's insect fauna was taking shape.

In 1990 the Scottish Entomologists were invited to carry out a week-long survey between 25 and 29 June. There were 22 participants and, this time, their remit was not confined to insects. Spiders were also investigated. The results again contributed substantially to our knowledge of the invertebrate fauna (Hancock, 1992 and Whitely, 1994).

During the next 10 years reports from visiting entomologists were again brought together and incorporated in the master list along with observations of residents and visiting naturalists included in the wildlife reports instigated by the late Wilf Nelson and periodically produced by Scottish Natural Heritage.

In late August/early September 2000 the Scottish Entomologists' gathering was again held on Rum. Again, the remit was not confined to insects and, this time, in addition to spiders, harvestmen and pseudoscorpions, the island's molluscs, Crustacea (Isopoda), Diplopoda (Millipedes) and Chilopoda (Centipedes) were also investigated, apparently for the first time!

The week-long search was probably one of the most successful of all the group surveys to date providing not only 76 new species of insects but a great deal of detailed information on distribution as well as useful data on the

colonisation by arboreal species of the new native woodlands restored since 1959. The inclusion of map references for all records was particularly useful and there were many records from widely dispersed localities.

Master lists of insect orders updated to 1999 (Wormell, in prep.) were handed out to participants at the beginning of the survey. These now provided a reasonably comprehensive appraisal of the insect fauna of the island and also gave an indication which groups required further investigation.

Sadly, David Philips, one of the most enthusiastic of the group, died in November 2003. His chosen specialist group was Tipulidae (Diptera), but he also included valuable records of Hemiptera, Orthoptera and Hymenoptera, finding 5 previously unrecorded species as well as gathering substantial new information on distribution within the island of previously recorded species. He will be greatly missed at future gatherings.

David Beaumont visited the island in May and July 2000 to set out pitfall traps at the following localities:

Kilmory Fank Tree Plot	(NG363008)
Harris Tree Plot	(NM338961)
Guiridil Tree Plot	(NG319008)
Kinloch (behind The White House)	(NM402992)
North face of Hallival at 500 m	(NM392967)

His trappings produced an enormous amount of new information including a substantial number of previously unrecorded Coleoptera as well as spiders.

This paper deals only with the insects recorded during the week-long survey including material from the pitfall trappings plus a few recorded from samples of leaf litter collected by Kathy Sayer and Malcolm Whitmore in December 2000 and extracted by Gordon Corbet. Dr Corbet has agreed to bring together the substantial lists of other invertebrate groups, namely Mollusca, Crustacea (Isopoda), Arachnida (spiders, pseudoscorpions and harvestmen), Diplopoda (Millipedes), Chilopoda (centipedes) in collaboration with David Beaumont and Mike Davidson.

Perhaps the two most interesting species encountered during this survey were *Gyrophaena poweri*, Crotch, a previously unrecorded saphylinid beetle associated with woodland fungi (Welch, 2001 & 2003) and *Cosmopterix orichalcea* (Stainton), Cosmopterigidae, a small leaf mining moth whose larvae were found by Keith Bland, in *Anthoxanthum*, from two new localities at Kinloch and Kilmory. The only previous record of the latter was a single imago collected by Peter Wormell in the Harris tree plot in June 1967 and determined by Ted Pelham-Clinton (Pelham-Clinton, 1986). Both of these rare insects were, until the 1970s, thought to be confined to a few scattered localities in southern England and, in the case of the latter, also in south Wales and Ireland. Their discovery, as resident populations on the Isle of Rum, is quite remarkable.

INSECTS RECORDED

Previously unrecorded species are indicated with an asterisk.

SMALL ORDERS AND HEMIPTERA

None of the participants on this survey concentrated on these orders, however, casual records by Gordon Corbet, Keith Bland, Roger and Rosy Key, Colin Welch, David Phillips and Peter Wormell resulted in useful new information on the distribution of some Odonata, Plecoptera, Orthoptera, Hemiptera and Neuroptera with 6 previously unrecorded species (1 Psocoptera, 4 Hemiptera and 2 Neuroptera).

ODONATA (Dragon Flies)

Cordulegasteridae

Cordulegaster boltonii (Donovan). Kinloch (NM4099) one 30.8.00 (KB).

Aeschnidae

Aeschna juncea (Linnaeus). Loch Gainmhich (NM3798) 30.8.00; (RK).

Libellulidae

Sympetrum danae Sulzer (= *S. scoticum* (Donovan)). Loch Gainmhich (NM3798) 30.8.00 (RK); Kilmory (NG3603) many 27.8.00; Harris (NM3396) 29.8.00, many (KB).

PLECOPTERA (Stoneflies)

Nemouridae

Leuctra fusca (Linnaeus). Widespread, Sgaorishal, Kilmory Fank Tree Plot on alder; Harris Tree Plot on ash, Harris fields, Kinloch Glen on alder and broom, August 2000 (GC).

ORTHOPTERA

Tetrigidae

Tetrix undulata (Sowerby). Kilmory Dunes (NG3604) 27.8.00 (RK).

Acrididae

Omocestus viridulus (Linnaeus). Kilmory, flushes near cottage (NG358039) and dunes (NG3604) 27.8.00 (DP).

Myrmeleotettix maculatus (Thunberg). Kilmory Dunes (NG3604) 27.8.00 (RK).

Chorthippus parallelus (Zetterstedt). Kilmory, flushes near cottage (NG358039) and beach (NG366044) 27.8.00 (DP).

DERMAPTERA (Earwigs)
Forficulidae
Forficula auricularia Linnaeus. Kilmory Dunes (NG3604) 27.8.00; Harris (NM3495) 29.8.00 (RK); Kinloch (NM4099) 30.8.00 (KB).

PSOCOPTERA (Booklice)
**Lepinotus reticulatus* Enderlein. ♀♀, sieving hay in the Kinloch Farm barns, 31.8.00 (RCW).

HEMIPTERA HETEROPTERA
Pentatomidae
Picromerus bidens (Linnaeus). Kinloch (NG3900) 29.8.00, attacking heather beetle (C Allen det. KB).
Rhacognathus punctatus (Linnaeus). Lower slopes of Hallival, (475 m), (NM392969) 28.8.00 (DH) (Horsfield, 2002)
Lygaeidae
Stygnocoris sabulosus (Schilling). Kilmory enclosure, one swept from Calluna/Erica/grass, August 2000 (GC).
Miridae
Dicyphus pallicornis (Meyer-Dür). Kilmory (NG3503) few among leaves of Digitalis 27.8.00 (KB).
Calocoris roseomaculatus (De Geer). Kilmory Dunes (NG3604) 27.8.00, common (RK).
Saldidae
Saldula scotica (Curtis). Loch Fiachanis (NM3594) and Loch Gainmhich (NM7398) 30.8.00, common in both lochs (RK).
S. saltatoria (Linnaeus). Coire Dubh (NM3897) 28.8.00 and Loch Gainmhich (NM7398) 30.8.00, common (RK).
Veliidae
Velia caprai Tamanini. Barkeval summit (NM3797), 30.8.00 (RK).
Gerridae
Gerris costai (Herrich-Schaeffer). Near Dibidil (NM4094) 1 ♀ 28.8.00 (KB det. T. Huxley).
Nepidae
Nepa cinerea Linnaeus. Harris (NM340953), Juv in plastic bucket in small stream below boulder beach, 29.8.00 (RCW). (Specimen now held by T. Huxley)
Corixidae
Sigara nigrolineata (Fieber). Harris (NM341955), 4 ♂♂ and 3 ♀♀, pool behind raised beach, 25.8.00 (PW det. T. Huxley).
S. scotti (Fieber). Harris (NM341955) one ♂ and 5 ♀♀, pool behind raised beach, 25.8.00 (PW det. T. Huxley).
S. venusta (Douglas & Scott). Harris (NM341955) 2 ♂♂ and 5 ♀♀, pool behind raised beach, 25.8.00 (PW det. T. Huxley).

HEMIPTERA-HOMOPTERA
Cercopidae
Phylaenus spumarius (Linnaeus). Kinloch Castle, grassland, (NM400995), 23.8.00; Kinloch Glen, heath (NM378997), 30.8.00; mine (NG383003) 31.8.00; Kinloch, grassland, (NM402998) 1.9.00 and mine (NM404898) 1.9.00 (DH).
Cixidae
Cixius nervosus (Linnaeus). Kinloch Glen (NM396999), ♀ on alder, August 2000 (GC).
Psyllidae
**Trioza remota* Foerster. Kinloch Glen (NG3900), Psyllid pits in underside of oak leaves, 31 August 2000 (KB).
Livia juncorum (Latreille). Askival/Hallival ridge (NM3996) galls on *Juncus articulatus*; Harris (NM3495) (Linnaeus) shoot galls on *J. articulatus*, 29 August 2000 (KB).
**Psyllopsis fraxini* (Linnaeus). Kinloch (NM4099) galled and crinkled leaf edges on ash, 30 August 2000 (KB).
Psylla alni (Linnaeus). Kinloch Glen (NM396999) ♀ on alder (GC).
Aphididae
**Dysaphis crataegi* (Kaltenach). Kilmory North Tree Plot (NG3602) 1 September 2000 and Kinloch (NM4099), curled and thickened leaves of hawthorn, 30 August 2000 (KB).
Myzus cerasi (Fabricius). Kinloch (NM4099), rolled and crinkled leaves of cherry, 30 August 2000 (KB).

NEUROPTERA
Chrysopidae
**Chrysoperla carnea* Stephens. Harris Tree Plot, one on hawthorn, August 2000 (GC).
Hemerobiidae
Hemerobius simulans Walker. Harris Tree Plot, one on hawthorn, August 2000 (GC).

Contributors (Small Orders & Hemiptera)

KB	=	Dr Keith Bland
GC	=	Dr Gordon Corbet
DH	=	Dr D Horsfield
RK	=	Dr Roger & Rosy Key
DP	=	Dr David Phillips
RCW	=	Dr R C Welch
PW	=	Peter Wormell

LEPIDOPTERA
The butterflies and moths have received more sustained attention over the years than other insect orders since a few residents, with an interest particularly in the Macrolepidoptera, have been able to record and collect at all seasons since the island became a National Nature Reserve in 1957. Some families belonging to the Microlepidoptera have, however, been neglected.
Contributors to this section were Caroline Allen (CA), David Barbour (DAB), Keith Bland (KB), Gordon Corbert (GC), Michael Davidson (MD), David Horsfield (DH), Roger and Rosy Key (RK), Jessie MacKay (JM), Colin Welch (RCW) and Peter Wormell (PW). Nineteen new species were added to the island's checklist.
Keith Bland concentrated on families which had received the least attention in the past, i.e. Nepticulidae, Bucculatriidae, Lyonetiidae, Gracillariidae, Glyphipterigidae, Yponomeutidae, Coleophoridae, Oecophoridae, Gelechiidae, Momphidae and Cosmopterigidae. Within these families he recorded 16 previously unrecorded species. His most interesting discovery was of larval mines of *Cosmopterix orichalcea* in *Anthoxanthum* at Kilmory and Kinloch (Bland 2001). Twenty-two imagines emerged between 10 and 15 May 2001. The only previous record of this species was a single imago netted by Peter Wormell in a dense mat of *Festuca rubra* in the Harris Tree Plot on 26 June 1967 and determined by Ted Pelham Clinton (Pelham-Clinton, 1986). These would seem to be the only records so far for this leaf miner in Scotland.
Peter Wormell, Caroline Allen, Jessie MacKay and David Barbour carried out moth trappings in the vegetation monitoring enclosure on Kilmory machair, Kilmory and Harris Tree Plots, Harris Mausoleum enclosures on the north side of Loch Scresort, at various sites in the Kinloch Policies and in the Kinloch Glen. One Tortricid *Acleris comariana* (the Strawberry Tortrix), new to the Rum list, was trapped in the Kinloch Glen and a new Pyralid *Eudonia murana* at several localities in the Kinloch area.
Caroline Allen collected and reared larvae including *Peridroma saucia* (the Pearly Underwing). It has been stated that there is evidence to support the suggestion that this species could be a permanent resident in some sheltered nooks in milder areas in Britain (South, 1908) though Heath & Emmet (Vol. 9, 1979) suggest this is unlikely. However, since breeding was also confirmed in the 1960s (Wormell 1982) it would seem possible that a small resident population may, indeed, have become established.
David Barbour recorded several males of *Orgyia antiqua* (the Vapourer), for the first time on Rum, on the north side of Loch Scresort. Taking into consideration the sedentary nature of the flightless female of this species it raises questions about its colonisation history.
Nineteen new species were added to the island's checklist.

Nepticulidae
*23 *Ectoedemia argyropeza* (Zeller). Loch Scresort South Side Nature Trail (NM4198) early mines in petioles of aspen, 31.8.00 (KB).
34 *E. occultella* (Linnaeus)(=*argentipedella*). Loch Scresort south side (NM4199) 31.8.00, early mines in birch (KB).
35 *E. minimella* (Zetterstedt) (=*mediofasciella* auct). Kinloch (NM4099) 30.8.00, a few empty mines in birch (KB); Bagh na h-Uamha (NM4197) 1.9.00, mines in birch (RCW).
*50 *Stigmella aurella* (Fabricius). Harris Tree Plot (NM3396) 29.8.00, single vacated mine in bramble (KB).
66 *Stigmella sorbi* (Stainton). Dibidil Track (NM4096), old mines on rowan; Allt Slugan a Choilich (NM3998), near Hydro Dam, mines in rowan, 28.8.00; Harris Tree Plot (NM3396), many old larval mines in rowan 29.8.00; Kilmory (NG3603), more vacated mines 1.9.00 (KB).

68 *S. salicis* (Stainton). Kinloch (NM4099) 30.8.00; Kinloch Glen (NG3900, 4000) 31.8.00, vacated mines in *Salix cinerea*; Kilmory Fank Tree Plot (NG3600), vacated mines in *Salix aurita*; Kilmory outwith Tree Plots (NG3603) 1.9.00 (KB).

*72 *S. myrtillella* (Stainton). Loch Scresort, South Side Nature Trail (NM4198), single vacated mine in blaeberry, 31.8.00 (KB).

*79 *S perpygmaeella* (Doubleday). Kinloch (NM4099), mines on hawthorn, 30.8.00; Kilmory north enclosure (NG3603) 1.9.00, vacated mines in hawthorn (KB).

87 *S. svenssoni* (Johansson). Harris Tree Plot (NM3396), many vacated linear mines in oak, 29.8.99; Kinloch Glen (NG4000) 31.8.00, mines (KB).

99 *S. hybnerella* (Hübner). Kinloch (NM4099), vacated mines on hawthorn, 30.8.00 (KB).

103 *S. nylandriella* (Tengström) (= *aucupariae* Freyer). Kinloch near castle (NM4099) 27 & 30 8.00, mines in rowan (KB); Harris Tree Plot (NM3396) 29.8.00, vacated mines in rowan (JM).

*104 *S. magdalenae* (Klimesch). Kinloch (NM4099), many mines on rowan, 30.8.00; Harris Tree Plot (NM3396) 1.9.00, a few vacated mines on rowan (KB).

*108 *S. crataegella* (Klimesch). Harris Tree Plot, many vacated mines, (1 occupied) 29.8.00 (KB)

*112 *S. luteella* (Stainton). Kilmory Fank Tree Plot (NG3600), single mines on birch, 1.9.00 (KB).

*115 *S. alnetella* (Stainton). Kilmory North Tree Plot (NG3603), a few vacated mines in alder, 1.9.00 (KB)

116 *S. lapponica* (Wocke). Kinloch, vacated mines in birch (NM4099) 28.8.00 (KB); Kilmory Fank Tree Plot (NG3602); Bagh na h-Uamha near standing stone (NM4197), vacated mines on birch, 1.9.00 (RCW).

117 *S. confusella* (Wood). Kinloch (NM4099), mines in birch, 30.8.00 (KB); Bagh na h-Uamha near standing stone (NM4197), vacated mines in birch, 1.9.00 (RCW).

Incurvariidae

128 *Phylloporia bistrigella* (Haworth). Kilmory (NG3603), old mines in leaves of birch, 27.8.00; Kinloch (NM4099), vacated mines in birch, 28.8.00; Kilmory Fank Tree Plot (NG3600), vacated mines on birch, 1.9.00; Kilmory North Plot (NG3603), aborted mines on birch, 1.9.00 (KB).

132 *Incurvaria praelatella* (Denis & Schiffermüller). Kinloch (NM4099), early mines, just cutting out, in leaves of *Filipendula ulmaria,* 30.8.00 (KB).

Heliozelidae

*154 *Heliozela sericiella* (Haworth). Kilmory (NG3603, many vacated mines in oak, 27.8.00; South Side Loch Scresort (NM4099, 4198, 4199), vacated mines on oak, some parasitised, 31.8.00; Kinloch Glen (NG3900, 4000), many vacated mines, 31.8.00; Kilmory North Tree Plot (NG3602-3603) 1.9.00, a few vacated mines on oak (KB).

156 *H. resplendella* (Stainton). Kilmory (NG3603), many vacated mines in alder, 27.8.00 and a few on 1.9.00, one with parasites - one ualcid emerged 10.9.00; Kinloch (NM4099) 30.8.00 (KB).

157 *H. hammoniella* (Sorhagen). Kinloch (NM4099), vacated mines in birch, 28.8.00 and 30.8.00 (KB).

Zygaenidae

169 *Zygaena filipendulae* (Linnaeus). Harris (NM3396), single cocoon with exuvium on grass, 29.8.00 (KB).

172 *Zygaena purpuralis* (Brünnich). Harris (NM3396), 5 larvae feeding on *Thymus* (KB); 2 retained and passed to P. Wormell but did not survive diapause (PW).

Tineidae

227 *Monopis laevigella* (Denis & Schiffermüller). Kinloch Castle (NM4099) 1.9.00, one dead indoors (KB).

Ochsenheimeriidae

252 *Ochsenheimeria urella* Fischer von Rösterstamm. Kilmory Fank (NG3600) 27.8.00, pair in cop. swept by track (KB).

Lyonetiidae

*257 *Leucoptera orobi* (Stainton). Kinloch Glen (NG3900) 31.8.00, larvae mining leaves of *Trifolium pratense*, (DH), imagines emerged 13.5.01 (KB). New food plant in Britain (Bland, 2001).

Bucculatriidae

*272 *Bucculatrix cidarella* Zeller. Dibidil track (NM4097), mines with moulting cocoons on leaves of alder, 28.8.00; Kinloch (NM4099) 30.8.00; Kinloch Glen (NG3900 and 4000) 31.8.00 (KB); Kinloch Glen Nature Trail (NM3999) 29.8.00, larva on alder (CA).

*274 *B. ulmella* Zeller. Kinloch Glen (NG3900 and 4000), vacated mines in oak, 31.8.00 (KB).

276 *B. demaryella* (Duponchel). Kilmory Fank Tree Plot (NG3600), a few vacated mines on birch, 1.9.00 (KB).

Gracillariidae

282 *Caloptilia elongella* (Linnaeus). Kilmory North Tree Plot (NG3603), blisters and tubes etc on alder, 27.8.00; Kinloch (NM4099), rolls and early mines on alder, 30.8.00 (KB).

283 *C. betulicola* (Hering). Kinloch (NM4099), transverse rolls and early mines on birch, 30.8.00 (KB).

*284 *C. rufipennella* (Hübner). Kinloch (NM4099), cones on sycamore, 29.8.00 (KB); North Side, Loch Scresort (NM410999) 30.8.00 (CA).

286 *C. alchimiella* (Scopoli). Harris Tree Plot (NM3396), a few cones etc on oak leaves, 29.8.00 (KB) and 1.9.00 (JM); also cocoon on oak, 1.9.00 (CA).

288 *C. stigmatella* (Fabricius). Kilmory (NG3603), cones etc on *Salix repens*, 27.8.00; Kinloch (NM4099) 30.8.00 (KB).

293 *C. syringella* (Fabricius). Harris (NM3396), in Tree Plot, adults and larval workings, 29.8.00 (KB) and 1.9.00 (JM); Kinloch (NM4099), spinnings on ash and privet, 30.8.00; South Side Loch Scresort (NM4099, 4198 and 4199), few (KB).

*303 *Parornix anglicella* (Stainton). Harris Tree Plot (NM3396), a few cones on hawthorn, 29.8.00 (KB).

305 *P. scoticella* (Stainton). Kilmory (NG3603), folds and blisters in rowan, 27.8.00; Allt Slugan na Choilich nr Hydro Dam (NM3998) 28.8.00; Harris Tree Plot (NM3396), folds etc in rowan, 29.8.00; Kinloch (NM4099) 30.8.00 (KB).

320 *Phyllonorycter quercifoliella* Zeller. Harris Tree Plot (NM3396), blisters with frass covered cocoons, a few, 29.8.00 (KB).

337 *P. hilarella* (Zetterstedt) (=*spinolella* (Duponchel)). Kinloch (NM4099), blisters on leaves on *Salix cinerea* (KB).

341 *P. maestingella* (Müller). Kinloch (NM4099), a few blisters on beech, 30.8.00 (KB).

345 *P. rajella* (Linnaeus). South Side Loch Scresort (NM4198), blisters with exuvia on alder, 31.8.00 (KB).

*348 *P. quinqueguttella* (Stainton). Kinloch (NM4099), single blister on *Salix repens,* 30.8.00 (KB).

353 *P. ulmifoliella* (Hübner). Kilmory (NG3603), in Tree Plot, blisters in leaves of birch, 27.8.00; Kilmory Fank Tree Plot (NG3600), vacated mines on birch (KB).

*354 *P. emberizaepenella* (Bouché). Kilmory (NG3603), blisters with contortion of leaf on *Lonicera,* 27.8.00 (KB).

Choreutidae

385 *Anthophila fabriciana* (Linnaeus). Kinloch (NM4099), many webs on *Urtica dioica,* 30.8.00 (KB).

Glyphipterigidae

391 *Glyphipterix simpliciella* (Stephens). Kinloch (NM4099), typical holes in stem of *Dactylis glomerata,* 30.8.00 (KB).

392 *G. schoenicolella* Boyd. Dibidil track (NM4194), larvae in seed heads of *Schoenus nigricans* (KB).

Yponomeutidae

411 *Argyresthia goedartella* (Linnaeus). Kinloch (NM4099), one, 30.8.00 (KB); South Side Wood Loch Scresort (NM416989) 31.8.00 (JM); MV trap near the turbine (NM399994), several, 30.8.00 (PW, JM, CA).

*419 *A. semifusca* (Haworth). MV trap near the turbine (NM399994) 30.8.00 (PW, JM, CA, DAB).

421 *A. bonnetella* (Linnaeus). Harris Tree Plot (NM3396), two, 29.8.00 (KB).

437 *Swammerdamia caesiella* (Hübner). Kinloch (NM4099), single larva in web on birch, 30.8.00 (KB).

461 *Ypsolopha ustella* (Clerck). MV trap near the turbine, Kinloch (NM399994) 30.8.00; Peat Pool, Kinloch Glen, MV trap 29.8.00 (JM, CA, PW, DAB).

464 *Plutella xylostella* (Linnaeus). One, Kilmory (NG3603) 27.8.00; one, Askival (NM3994) (KB).

Coleophoridae

493 *Coleophora serratella* (Linnaeus). Single case on birch, Kinloch (NM4099) 28.8.00 (KB).

547 *C. discordella* Zeller. Kinloch Glen (NG4000), single case feeding on *Lotus corniculatus* (KB).

*553 *C. striatipennella* Nylander. Kinloch (NM4099), cases on seedheads of *Stellaria alsine,* 30.8.00 (KB).

564 *C. obscenella* Herrich-Schäffer (=*C. virgaureae* (Stainton)). Dibidil track (NM4195), many cases on flowerheads of *Solidago virgaurea,*28.8.00 (KB). South side of Loch Scresort; 30 August 1969; one case on *Solidago virgaurea*; (ECP-C).

584 *C. alticolella* (Zeller). Kilmory cases on *Juncus,* (NG3503) 27.8.00; Kinloch (NM4099) 30.8.00 (KB); Kinloch Glen Nature Trail (NM3999) 29.8.00 (CA).

Oecophoridae

647 *Hofmannophila pseudospretella* (Stainton). Kinloch Castle windowsill, 30.8.00 (JM).

670 *Depressaria daucella* (Denis & Schiffermüller). Kinloch (NM4099), workings and pupae on *Oenanthe sp*, 30.8.00 (KB).

Gelechiidae

821 *Scrobipalpa murinella* (Duponchel). Askival/Hallival Coll (NM3995) 28.8.00, at least two sets of mines in *Antennaria dioica* (KB).

822 *S. acuminatella* (Sircom). Harris (NM3396), steep sided burn, Glen Duain, many mines in *Cirsium palustre* (KB).

829 *Caryocolum marmoreum* (Haworth). Shamhnan Insir (NG3704) 27.8.00, one female (RK det KB, genitalia checked).

843 *Aproaerema anthyllidella* (Hübner). Harris (NM3396), a few empty podded leaves of *Anthyllis vulneraria,* 29.8.00 (KB).

858 *Hypatima rhomboidella* (Linnaeus) MV Trap, Turbine House, Kinloch (NM399994) 30.8.00 (PW, CA, JM, DAB).

Momphidae

883 *Mompha raschkiella* (Zeller). South Side Loch Scresort (NM4099, 4198, 4199), mines in rose bay willow herb, 31.8.00 (KB).

Cosmopterigidae

896 *Cosmopterix orichalcea* (Stainton). Kilmory (NG3603), larvae in mines on *Anthoxanthum*, 27.8.00 and 1.9.00; Kinloch (NM4099), linear leaf mines with no frass again in *Anthoxanthum*, 30.8.00. These were all pooled to maximise breeding success. On 25.4.01 two larvae had just pupated, others were still larval. One imago emerged 10.5.01, 4 more emerged on 11.5.01, 8 on 12.5.01, 5 on 13.5.01, 2 on 14.5.01 and 2 on15.5.01 (KB).

Tortricidae

1029 *Eana osseana* (Scopoli). One, Askival (NM3894) 28.8.00 (KB). Kilmory dunes (NG363037) 28.8.00 and wet meadows (NG367045) 27.8.00 (JM).

1038 *Acleris laterana* (Fabricius). Kinloch (NM4099) one (KB) and in UV trap Rose Garden (playpark) (NM402995) 31.8.00 (JM, CA).

*1039 *A. comariana* (Lienig & Zeller). Strawberry Tortrix. Peat Pool, Kinloch Glen, MV trap (NG395001) 29.8.00 (PW, CA, JM, DAB).

1040 *A. caledoniana* (Stephens). Above Dibidil track near Beinn nan Stac (NM405942), base rich area, (male gen.ch'd) 28.8.00 (KB).

1041 *A. sparsana* (Denis & Schiffermüller). Kinloch near turbine, MV trap (NM399994) 30.8.00 (PW, JM, CA, DAB).

1042 *A. rhombana* (Denis & Schiffermüller). Rhomboid Tortrix. Kilmory North Tree Plot (NG3505), several, 27.8.00; Harris Tree Plot (NM3396), one, 29.8.00; Kilmory Fank Tree Plot (NG3600), one, 1.9.00 (KB); Kinloch Glen (NG395001), MV trap, 29.8.00 (JM, PW, CA, DAB); Kilmory Dunes from hawthorn (NG361038), and wet meadow (NG367045) 27.8.00 (JM); Samhnan Insir (NG373043) 27.8.00 (JM); Kilmory Glen Stream Plot (NG364010) 28.8.00, MV trap (PW, JM, CA); Harris Tree Plot (NM338962) net, 1.9.00 (JM).

1043 *A. aspersana* (Hübner) Kilmory Coast (NG361038) net, 27.8.00 (JM). Harris Tree Plot (NM338962), UV trap 1.9.00 (JM and CA).

1048 *A. variegana* (Denis & Schiffermüller) Garden Rose Tortrix. Kilmory (NG3603) several from rowan and rose and a single pupa in folded leaf of bramble, 27.8.00, one imago emerged 10.9.00, also one imago netted 1.9.00 (KB).

1062 *A. emargana* (Fabricius). Kinloch near turbine (NM399994), MV trap, 30.8.00 (JM, CA, PW, DAB); Peat Pool Kinloch Glen, UV trap (NG394002) 29.8.00 (JM, PW, CA, DAB); Kilmory Glen, Stream Plot (NG364010) 28.8.00, MV trap (PW, CA, JM).

1111 *Bactra lancealana* (Hübner). Peat Pool Kinloch Glen MV trap (NG395001) 29.8.00, also UV trap (NG394002) 29.8.00 (JM, PW, CA, DAB).

1119 *Ancylis geminana* (Donovan). Allt Slugan a Choillich Hydro dam (NM3998), larval workings on leaves of *Salix cinerea* sub sp *oleifolia* (det D. Meikle); Kinloch (NM4099), larval workings on *Salix cinerea,*30.8.00 (KB).

1132 *Epinotia subocellana* (Donovan). Kilmory, 27.8.00 and 1.9.00 (NG3503), larvae under fluff on *Salix aurita* leaves; Kilmory South Tree Plot (NG3603) (natural regeneration), and Kilmory North Tree Plot (NG3603) 1.9.00 (KB); larval workings, Dibidil track (NM4096) 28.8.00; Kinloch (NM4099), larvae under white felt mat on leaves of *Salix aurita x cinerea* (KB).

1134 *E. ramella* (Linnaeus). North Side Loch Scresort (NM410999), UV trap, 30.8.00 (JM); Peat Pool Kinloch Glen (NG395001) 29.8.00, MV trap (PW, CA, JM, DAB); Streamside Tree Plot Kilmory Glen (NG364010), MV trap (PW, JM, CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

1136 *E. immundana* (Fischer von Röslerstamm). Harris Tree Plot (NM3396), one, 29.8.00; South Side Loch Scresort (NM4198) 31.8.00; Kilmory Fank Tree Plot (NG3600) and Kilmory North Tree Plot (NG3603) 1.9.00 (KB); Kinloch Castle rear, UV trap, 30.8.00; Peat Pool Kinloch Glen, MV trap (NG395001) 29.8.00 (JM, CA, PW, DAB); Kilmory Glen (NG3603), netted 28.8.00, (JM); Streamside Tree Plot (NG364010) 28.8.00, MV trap (JM, CA, PW).

1137 *E. tetraquatrana* (Haworth). Kinloch (NM4099), borings in young twigs of birch, 30.8.00 (KB).

1139 *E. tenerana* (Denis & Schiffermüller). Nut Bud Moth. Harris Tree Plot (NM3396), one, 29.8.00; Kinloch (NM4099), one, 30.8.00; Kilmory Fank Tree Plot (NG3600) 1.9.00 (KB); South Side Wood Loch Scresort (NM414989) 31.8.00 (JM, KB); Kilmory Fank Tree Plot (NG363008) 27.8.00 (JM) and 1.9.00 (KB).

1151 *E. tigonella* (Linnaeus) (= *E. stroemiana* (Fabricius)). Kilmory North Tree Plot (NG3503), one, 27.8.00; South Side Loch Scresort (NM4198), one, 31.8.00 (KB); Peat Pool Kinloch Glen, MV trap (NG395001)

29.8.00 (PW, JM, CA, DAB); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

1155 *E. brunnichana* (Linnaeus). Peat Pool Kinloch Glen MV trap (NG395001) 29.8.00 (PW, CA, JM, DAB); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

1156 *E. solandriana* (Linnaeus). Peat Pool Kiloch Glen MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA); netted Kilmory Dunes (NX363037) 28.8.00 (JM).

1159 *Rhopobota naevana* (Hübner) (=*R. unipunctana* (Haworth). Holly Tortrix. Kilmory North Tree Plot (NG3503) one 27.8.00; Dibidil track (NM4097) one 28.8.00; South Side Loch Scresort (NM4198) 31.8.00 (KB).

*1164 *Zeiraphera rufimitrana* (Herrich-Schäffer). Peat Pool Kinloch Glen, MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB).

*1165 *Z. isertana* (Fabricius). Harris Tree Plot (NM3396), one, 29.8.00 (KB).

1184 *Epiblema cirsiana* (Zeller). Harris (NM3396), single large bright reddish larva in stem of *Cirsium palustre* 29.8.00 (KB).

Pyralidae

1302 *Crambus perlella* (Scopoli). Kilmory (NG3503 and NG3603) two 27.8.00 (KB).

1304 *Agriphila straminella* (Denis & Schiffermüller). Near Kinloch Castle, MV trap (NM401995) 24.8.00 (PW); Kilmory Graveyard (NG361037) 27.8.00 (JM).

1305 *A. tristella* (Denis & Schiffermüller). Kilmory Graveyard (NG361037) 27.8.00 (JM).

1306 *A. inquinatella* (Denis & Schiffermüller). Kilmory (NG3603) few 27.8.00 (KB).

1314 *Catoptria margaritella* (Denis & Schiffermüller). Kinloch Castle MV trap (NM401995) 24.8.00 (PW); Samhnan Insir (NG371041) 27.8.00; Kilmory Glen (NG365036) 27.8.00 (JM).

*1339 *Eudonia murana* (Curtis). Kinloch Castle rear (NM400995), UV trap, 30.8.00 (DAB, CA, JM); at the School (NM409990) 31.8.00 (JM); Peat Pool Kinloch Glen, MV trap (NG395001) 29.8.00 (PW, JM, DAB, CA).

1344 *E. mercurella* (Linnaeus). Kinloch (NM4099), one to light, 29.8.00 (KB); South Side Loch Scresort (NM4198) 31.8.00 (KB); Kinloch Rose Garden (Play Park) (NM402992), UV trap, 31.8.00 (JM, CA); School, netted (NM409990) 31.8.00 (JM); Turbine, MV trap (NM399994) 30.8.00 (PW, JM, CA, DAB).

1345 *Elophila nymphaeata* (Linnaeus). Kilmory (NG3603) many larval cases on Potamogeton leaves, almost certainly this species 1.9.00 (KB).

1356 *Evergestis forficalis* (Linnaeus). Garden Pebble. Kinloch, Rose Garden (NM402995) 30.8.00 (CA).

1388 *Udea lutealis* (Hübner). Kinloch near Castle (NM4099) 27.8.00, one, and a few on 30.8.00; Harris Tree Plot (NM3396), one only, 29.8.00 (KB); Kinloch, near White House (NM403993), netted, 26.8.00 (JM); Kinloch, Rose Garden (NM402992) 30.8.00 (CA).

1398 *Nomophila noctuella* (Denis & Schiffermüller). Rush Veneer. Kilmory (NG3503 and NM3603), many, 27.8.00; Dibidil Track (NM4096 and 4195) and base rich area (NM405942) where a single brown larva was found under edge of stone, 28.8.00 (pupated 6.9.00; imago emerged 20.9.00) (KB); imagines at Askival (NM3994) 28.8.00; Harris (NM3396), very abundant, 29.8.00; Kinloch (NM4099) several, 30.8.00 (KB); Kinloch Castle side, MV trap (NM401995), swarming, 24.8.00 (PW); Turbine, MV trap (NM399994), much smaller numbers, 30.8.00 (PW); numerous sightings Nature Trail (NG3800) 29.8.00 (CA); Kilmory (NG3603, NG3704), 27.8.00; (JM, CA, PW); Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (JM, CA, PW); Harris Mausoleum (NM336957), MV trap, 1.9.00; Harris Tree Plot, UV trap (NM338962) 1.9.00 (JM, CA); Samhnan Insir (NG3704) 27.8.00 (RK).

1428 *Aphomia sociella* (Linnaeus). Bee Moth. Kinloch Rose Garden (Play Park) (NM402995), UV trap, 31.8.00 (JM, CA).

1454 *Dioryctria abietella* (Denis & Schiffermüller). Kinloch turbine, MV trap, (NM399994) 30.8.00 (PW, JM, CA, DAB).

Pieridae

1551 *P. napi* (Linnaeus). Green-Veined White. Kilmory (NG3603) one 27.8.00; Kinloch (NM4099) 30.8.00, a few (KB); common at Kinloch particularly around Hall (NM402997) 30.8.00 (JM); Kinloch Glen Nature Trail (NG3800-3900) 29.8.00 (CA).

Lycaenidae

1574 *Polyommatus icarus* (Rottemburg). Common Blue. Kilmory (NG3603) and Dunes (NG3604) adults & larvae 27.8.00 (KB, PW, JM, CA); Harris (NM3396), 29.8.00, 2 females and many young larvae on *Lotus coniculatus*; larvae on *Lotus* at Kinloch (NM4099) 30.8.00 (KB); Harris (NM3495) 29.8.00 (RK).

Nymphalidae

1590 *Vanessa atalanta* (Linnaeus). Red Admiral. Allt Slugan a Choillich, (nr Hydro Dam) (NM3998) 28.8.00; Kinloch (NM4099) 30.8.00 (KB); Coire Dubh (NM3897) 30.8.00 (RK).

1591 *Cynthia cardui* (Linnaeus) (= *Vanessa cardui* (Linnaeus)). Painted Lady. Kilmory, larva on *Cirsium arvense*, 27.8.00 (NG3503) (KB); Kinloch Glen on road (NM3999) 29.8.00 (CA); Kilmory Dunes (NG36040) imago and larva, 29.8.00; Harris (NM3495) 29.8.00 (RK).

1607 *Argynnis aglaja* (Linnaeus). Dark Green Fritillary. Harris (NM3396), raised beach, worn male, 29.8.00 (KB); Kilmory Dunes (NG3604) 27.8.00; Samhnan Insir (NG379043) 27.8.00; Harris (NM3495) 29.8.00 (RK).

1614 *Pararge aegeria* (Linnaeus). Speckled Wood. Kinloch (NM4099), one, 30.8.00; South Side Loch Scresort (NM4099, 4198 and 4199), several 31.9.00 (KB); Kinloch common on North Side (NM410999) 30.8.00; Kinloch Glen Nature Trail (NG3800-3900) 29.8.00 (CA).

1621 *Hipparchia semele* (Linnaeus). Grayling. Kilmory North East end of beach (NG367045) 27.8.00 (PW and JM); Samhnan Insir (NG379043) 27.8.00 (RK).

1626 *Maniola jurtina* (Linnaeus). Meadow Brown. Kilmory (NG3503 and NG3603), three imagines, 27.8.00; Kinloch Glen (NG4000), one, 31.8.00 (KB); Kilmory Graveyard (NG361037) and Kilmory Glen (NG365036 and 362032) 27.8.00 (JM, PW, CA).

Lasiocampidae

1637 *Lasiocampa quercus callunae* Palmer. Northern Eggar. Kinloch (NM4099), one small larva 30.8.00 (DP); an early larva on herbage, Kilmory (NG3603) 1.9.00 (KB).

1638 *Macrothylacia rubi* (Linnaeus). Fox Moth. Kilmory (NG3503, NG3600 and NG3603) 26.8.00, larvae common on various herbs; Kilmory South Tree Plot, 1.9.00 (NG3602) larva on *Salix aurita*; Kilmory North Tree Plot (NG3603), many, 1.9.00; Allt na Ba in Corrie (NM4094) one larva, 28.8.00 (KB); Kinloch Glen larvae common (NG3800) 29.8.00; Kilmory Glen and Coast (NG3603, 363008) 1.9.00 (JM, PW, CA); larvae, Kilmory (NG3604) and Samhnan Insir (NG379043) 27.8.00 (RK).

1640 *Euthrix potatoria* (Linnaeus). The Drinker. Kilmory (NG3503 and NG3603) 26.8.00, three small larvae on grass stems (KB); Kinloch, (NM4099), third grown larva, 30.8.00 (DP); larvae in Kinloch Glen (NG366044) 29.8.00, and Kilmory Glen (NG366044) 28.8.00 (CA); Kilmory Dunes (NG3604), Samhnan Insir (NG379043) and Kinloch Glen (NG 396000) 27.8.00 (RK).

Saturniidae

1643 *Saturnia pavonia* (Linnaeus). Emperor. Kilmory Fank (NG3600) 27.8.00, single larva; base rich area above Dibidil track (NM405942) 28.8.00, one fullgrown larva (KB).

Drepanidae

1655 *Tethea or* (Denis & Schiffermüller). Poplar Lutestring. South Side Loch Scresort (NM4198), a few larvae between leaves of aspen, 31.8.00; Kilmory North Tree Plot (NG3602), many vacated spinnings on aspen 1.9.00 (KB); Bagh na h-Uamha near Standing Stone (NM4197), larvae between leaves of aspen, 1.9.00 (RCW).

Geometridae

1716 *Rhodometra sacraria* (Linnaeus). Vestal. Kinloch Glen, single imago in MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB).

1722 *Xanthorhoe designata* (Hufnagel). Flame Carpet. Kinloch (NM4099), one, 27.8.00 and another to light, 29.8.00 (KB); Kinloch Castle side, MV trap (NM401995) 24.8.00 (PW); MV trap at turbine (NM399994) 30.8.00, and Castle rear UV trap (NM400995) 30.8.00 (PW, DAB, CA, JM); Rose Garden (Play Park), Kinloch parasitised larva, 30.8.00 (CA); Kinloch Glen Peat Pool, Alder Wood MV and UV traps (NG395001, 396000) 29.8.00 (JM, PW, DAB, CA).

1728 *X. fluctuata* (Linnaeus). Garden Carpet. South Side Loch Scresort (NM4198) 31.8.00, one (KB); Harris Tree Plot, UV trap (NM338962) 1.9.00 (JM, CA).

1732 *Scotopteryx chenopodiata* (Linnaeus). Shaded Broad-Bar. Kilmory (NG3603) 27.8.00, several (KB); Kilmory Glen, netted, (NG365036) 27.8.00 (JM).

1742 *Camptogramma bilineata* (Linnaeus). Yellow Shell. Kilmory (NG3603), one imago, 27.8.00; Kilmory Fank Tree Plot (NG3600), one, 1.9.00 (KB); Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

1752 *Cosmorhoe ocellata* (Linnaeus). Purple Bar. Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

1755 *Eulithis testata* (Linnaeus). Chevron. Kilmory (NG3603) 26.8.00; Kilmory South Tree Plot (NG3602) and Kilmory North Tree Plot (NG3602) 1.9.00; base rich area above Dibidil track (NM4094) 28.8.00; Harris (NM3495), several 29.8.00 (KB); North Side Loch Scresort (NM410999), UV trap, 30.8.00 (JM); MV trap, turbine at Kinloch (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; open alder wood UV trap (NG394002) 29.8.00 (JM,PW, CA, DAB); Kilmory, common (NG3704) 27.8.00; Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (JM, PW, CA); Harris Mausoleum enclosure, MV trap (NM336957) 1.9.00 (JM, CA).

1760 *Chloroclysta siterata* (Hufnagel). Red-Green Carpet. South Side Loch Scresort (NM4198), one, 31.8.00 (KB); North Side Loch Scresort (NM410999) 30.8.00; Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

1762 *C. citrata* (Linnaeus). Dark Marbled Carpet. Turbine, Kinloch, MV trap (NM399994) 30.8.00; Rose Garden (Play Park) (NM402995), UV trap, 31.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) and alder wood, UV trap (NG396000) 29.8.00 (PW, JM, CA. DAB); Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA); North Side Loch Scresort (NM410999), UV trap, 30.8.00 (JM).

1764 *C. truncata* (Hufnagel). Common Marbled Carpet. Kilmory (NG3503) 27.8.00, many (KB); Kilmory Fank (NG3600) 27.8.00, one by road; Kinloch (NM4099) rear Castle, 27.8.00; Dibidil track (NM4195) and Harris (NM3396) 29.8.00, a few; Harris Tree Plot (NM3396) 29.8.00, many; South Side Loch Scresort (NM4099, 4198, 4199), a few, 31.8.00; Kilmory Fank Tree Plot (NG3600) 1.9.00; Kilmory South Natural Regeneration Plot (NG3602) and Kilmory North Tree Plot (NG3603) 1.9.00 (KB); North Side Loch Scresort (NM410999), UV trap, 30.8.00 (JM); Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (JM, CA, PW, DAB); Kilmory Glen North and Fank Tree Plots (NG361032-363008) and Kilmory Coast (NG361038), netted; (JM); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

1767 *Thera firmata* (Hübner). Pine Carpet. North Side Loch Scresort (NM410999), UV trap, 30.8.00; Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool MV trap (NG395001) 29.8.00; alder wood, UV trap (NG396000) 29.8.00; open alder, UV trap (NG394002) 29.8.00 (DAB, JM, CA, PW); Kilmory Streamside Tree Plot (NG364010) 28.8.00, MV trap (PW, JM, CA).

1768 *T. obeliscata* (Hübner). Grey Pine Carpet. Kinloch Turbine, MV trap (NM399994) 30.8.00; Peat Pool, Kinloch Glen (NG395001) 29.8.00; open alder woodland, UV trap (NG394002) 29.8.00 (DAB, JM, PW, CA); Harris Tree Plot, UV trap (NM338962) 1.9.00 (JM, CA).

1777 *Hydriomena furcata* (Thunberg). July Highflyer. Harris Tree Plot (NM3396), one, 29.8.00 (KB); North Side Loch Scresort, UV trap (NM410999) (JM); Kinloch Turbine, MV trap (NM399994) 30.8.00 (PW, JM, DAB, CA).

1797 *Epirrita autumnata* (Borkhausen). Autumnal Moth. Kinloch Castle side, MV trap (NM401995) 24.8.00 (PW); Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, JM, CA); Harris Tree Plot, UV trap (NM338962) 1.9.00 (JM, CA).

1798 *E. filigrammaria* (Herrich-Schäffer). Small Autumnal Moth. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, JM, CA); Harris Tree Plot (NM338962), UV trap, (JM, CA).

1809 *Perizoma didymata* (Linnaeus). Twin-Spot Carpet. Kilmory (NG3503 and NG 3603), many 27.8.00; Dibidil track (NM4098, 4195 and 4196) 28.8.00; Allt Slugan a Coilich near Hydro Dam, 28.8.00; Harris (NM3396), raised beach, a few 29.8.00; Kinloch (NM4099), two, 30.8.00 (KB); Guiridil (NG3101) 30.8.00; (GC); South Side Wood Loch Scresort (NM415990) 31.8.00; near New Pier (NM411990) 31.8.00; White Gates (NM404992) 31.8.00 (JM); Kinloch Glen Nature Trail, common on heather (NG375006) 29.8.00 (CA); Samhnan Insir (NG371041) 27.8.00; Kilmory Fank Tree Plot (NG363008) 27.8.00 (JM); Kilmory Streamside Tree Plot (NG364010), MV trap 27.8.00 (JM, PW,CA); Kilmory Fank Tree Plot (NG3600) 1.9.00, few (KB).

1817 *Eupithecia pulchellata* Stephens. Foxglove Pug. Kilmory (NG3603) 27.8.00, holes and larval feeding in seedheads of *Digitalis purpurea* (KB).

1828 *E. satyrata* (Hübner). Satyr Pug. Kilmory (NG3603) 27.8.00, single larva on *Calluna vulgaris* (KB).

1851 *Eupithecia virgaureata* Doubleday. Golden-Rod Pug. Kinloch Castle rear,UV trap (NM400995) and Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (JM, PW, DAB, CA).

1867 *Aplocera plagiata* (Linnaeus). Treble-Bar. Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

1873 *Venusia cambrica* Curtis. Welsh Wave. South Side Loch Scresort (NM4198), one, 31.8.00 (KB); North Side (NM410999), UV trap, 30.8.00 (JM); Kinloch Turbine, MV trap (NM399994) 30.8.00; Castle rear, UV trap, 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (JM, PW, CA, DAB).

1884 *Abraxas grossulariata* (Linnaeus). Magpie. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB).

1887 *Lomaspilis marginata* (Linnaeus). Clouded Border. Kinloch Glen Peat Pool, MV trap, (NG395001), 29.8.00; open alder UV trap (NG394002) 29.8.00 (DAB, JM. CA, PW).

1906 *Opisthograptis luteolata* (Linnaeus). Brimstone Moth. Kinloch (NM4099), one, 30.8.00 (KB); Kinloch Turbine MV trap (NM399994) 30.8.00 (JM, CA, DAB, PW); larva, Kinloch (NM4090), reared, imago emerged 14.6.01 (CA).

1907 *Epione repandaria* (Hufnagel). Bordered Beauty. Kinloch Glen open alder woodland, UV trap (NG394002) 29.8.00 (PW, DAB, JM, CA); Kilmory Dunes, UV trap (NG363037) 28.8.00 (JM, CA, PW).

1941 *Alcis repandata* (Linnaeus). Mottled Beauty. Kinloch Castle rear (NM400995), UV trap, 30.8.00; Turbine, MV (NM399994) 30.8.00 (JM, CA, DAB, PW).

1961 *Campaea margaritata* (Linnaeus). Light Emerald. Kinloch Glen Peat Pool (NG395001), MV trap, 29.8.00 (JM, DAB, CA, PW).

Notodontidae

2003 *Nontodonta ziczac* (Linnaeus). Pebble Prominent. Larva, Dibidil track, Kinloch, one only, (NM404989) 31.8.00 (CA).

2007 *Pheosia tremula* (Clerck). Swallow Prominent. Kilmory North Tree Plot (NG3602), single larva on aspen, 1.9.00 (KB).

2008 *Ptilodon capucina* (Linnaeus). Coxcomb Prominent. Kinloch (NM4099), single half grown larva on alder, 30.8.00; South Side Loch Scresort (NM4198), single early larva feeding on oak, 31.8.00 (KB).

Lymantriidae

*2026 *Orgyia antiqua* (Linnaeus). Vapourer. Several males seen flying actively, Loch Scresort North shore (NM4199) 29.8.00 (DAB).

Arctiidae

2057 *Arctia caja* (Linnaeus). Garden Tiger. Kilmory (NG3503) 27.8.00, brood of early larvae on bramble (KB); Kinloch Castle side, MV trap (NM401995), one imago, 24.8.00 (PW).

2061 *Spilosoma luteum* (Huffnagel). Buff Ermine. Larvae on thistles at Kilmory (NG36 03) 30.8.00 (DAB).

2064 *Phragmatobia fuliginosa* (Linnaeus). Ruby Tiger. Kilmory (NG3503 and NG3603), several larvae on low herbs, 27.8.00 (KB); larvae, Kilmory and Kilmory Fank Tree Plot (NG371041 and NG363008) 27.8.00 (JM, CA); Kilmory Dunes (NG3604) 27.8.00 (RK).

Noctuidae

2082 *Euxoa nigricans* (Linnaeus). Garden Dart. Harris Tree Plot (NM338962), UV trap, 1.9.00; Mausoleum (NM336957), MV trap, 1.9.00 (JM, CA).

2104 *Standfussiana lucernea* (Linnaeus). Northern Rustic. Harris Tree Plot (NM338962), UV trap (JM, CA).

2107 *Noctua pronuba* (Linnaeus). Large Yellow Underwing. Kinloch Castle side, MV trap (NM401995) 24.8.00; Castle rear (NM400995), UV trap, 30.8.00; Kinloch Rose Garden (Play Park) (NM402995), UV trap, 31.8.00 (CA, JM); Kinloch Glen Peat Pool (NG395001) 29.8.00, MV trap (PW, DAB, CA, JM); Kilmory Dunes (NG363037) UV trap, 28.8.00; Kilmory Burnside Tree Plot (NG364010), MV trap, 28.8.00 (JM, CA, PW); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2109 *N. comes* (Hübner). Lesser Yellow Underwing. North Side Loch Scresort (NM410999) 30.8.00, UV trap; Castle side, MV trap (NM401995) 24.8.00 (PW); Turbine, MV trap (NM399994) 30.8.00; Rose Garden (NM402995), UV trap, 31.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; alder wood, UV trap (NG396000) 29.8.00 (JM, PW, CA, DAB); Kilmory Streamside Plot (NG364010), MV trap, 28.8.00 (JM, CA, PW); Harris Tree Plot (NM338962), UV trap, 1.9.00 (CA, JM); Dibidil Bothy (NM392927) (RCW).

2111 *N. janthe* (Borkhausen) (= *N. janthina auctorum*). Lesser Broad-Bordered Yellow Underwing. Kinloch (NM4099), near Castle, one, 27.8.00 (KB); Castle side (NM401995), MV, 24.8.00, abundant (PW); Turbine, MV trap (NM399994) 30.8.00; Rose Garden (Play Park) (NM402995), UV trap, 31.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) and Alder wood (NG396000) 29.8.00 (DAB, JM, CA, PW); Harris Tree Plot (NM338962) 1.9.00, UV trap (CA, JM).

2117 *Eugnorisma (=Paradiarsia) glareosa* (Esper). Autumnal Rustic. North Side Loch Scresort (NM410999), UV trap, 30.8.00; Kinloch Turbine, MV (NM399994) 30.8.00; Castle rear (NM400995),UV trap, 30.8.00; Rose Garden (NM402995), UV trap, 31.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; alder wood, UV trap (NG396000) 29.8.00; open alder, UV trap (NG394002) 29.8.00 (PW, DAB, JM, CA); Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA); Harris Tree Plot (NM338962) 1.9.00, UV trap (JM, CA).

2118 *Lycophotia porphyrea* (Denis & Schiffermüller). True Lovers Knot. Larva, Dibidil Track (NM4098) 31.8.00 (CA); Kinloch Glen alder wood, UV trap (NG396000) 29.8.00 (DAB, PW, JM, CA).

2119 *Peridroma saucia* (Hübner). Pearly Underwing. Larva, Kinloch, 30.8.00 (CA det. Roy Leverton). There is a slight authenticity problem over this record. The label on its container was, unfortunately, damaged during the winter. Very feint lettering was still discernable, as "? Garden". CA was collecting in the former Rose Garden now the children's play park (NM402992) on 30.8.00 and she is fairly certain that this was one of the larvae found on that day. Two earlier records of this species having bred, both in the vicinity of the Rose Garden, 22.8.60 and 20.9.66, coll, P. Wormell are significant. This is discussed further in the preamble.

2120 *Diarsia mendica* (Fabricius). Ingrailed Clay. Kinloch Castle side (NM401995) 24.8.00, MV trap (PW).

2121 *D. dahlii* (Hübner). Barred Chestnut. Kinloch Castle rear (NM400995), UV trap, 30.8.00; Rose Garden (NM402995), UV trap, 31.8.00; Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, JM, CA); Kilmory Glen Streamside Tree Plot (NG364010), MV trap,

28.8.00 (PW, JM, CA); Harris Tree Plot, UV trap (NM338962) and Mausoleum, MV trap (NM336957) 1.9.00 (JM, CA).

2130 *Xestia baja* (Denis & Schiffermüller). Dotted Clay. Kinloch Rose Garden (NM402995) 31.8.00; Kinloch Glen Peat Pool, MV trap (NG395001), 29.8.00 (PW, DAB, JM, CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2132 *X. castanea* (Esper). Neglected Rustic. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, JM, CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2134 *X. xanthographa* (Denis & Schiffermüller). Square-Spot Rustic. Kinloch (NM4099), near Castle, 27.8.00; Kilmory in Malaise Trap (NG3603), one, 31.8.00 (KB); Kinloch Castle rear, UV trap (NM400995) and Rose Garden (NM402995), UV trap, 31.8.00; Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; alder wood, UV trap (NG396000) 29.8.00; open alder UV trap (NG394002) 29.8.00 (PW, DAB, JM, CA); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, CA, JM); Harris Tree Plot (NM338962), UV trap and Mausoleum, MV trap (NM336957), 1.9.00 (JM, CA).

2135 *X. agathina* (Duponchel). Heath Rustic. North Side Loch Scresort (NM410999), UV trap, 30.8.00 (JM); Kinloch Turbine, MV trap (NM399994) 30.8.00; Larva on Dibidil Track (NM4098) 31.8.00 (CA); Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; alder wood, UV trap (NG396000) 29.8.00; open alder, UV trap (NG394002) 29.8.00 (PW, CA, JM, DAB).

2142 *Anarta myrtilli* (Linnaeus). Beautiful Yellow Underwing. Larva on heather, Kinloch Glen (NG372001) 30.8.00 (DAB).

2176 *Cerapteryx graminis* (Linnaeus). Antler Moth. Kinloch near Castle (NM4099) 27.8.00, one imago (KB) and another at a window, 26.8.00 (PW); Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA); Harris Tree Plot (NM338962), UV trap, and Mausoleum, MV trap (NM336957) 1.9.00 (JM, CA); Kilmory Dunes (NG3604) 27.8.00 (RK).

2177 *Tholera cespitis* (Denis & Schiffermüller). Hedge Rustic. Kinloch Turbine, MV trap (NM399994) 30.8.00 (PW, CA, DAB, JM); Kilmory Streamside Tree Plot (NG364010) 28.8.00 (JM, CA, PW).

2198 *Mythimna impura* (Hübner). Smoky Wainscot. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB).

2225 *Brachylomia viminalis* (Fabricius). Minor Shoulder Knot. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (JM, PW, CA, DAB); Kilmory Glen Streamside Plot (NG364010), MV trap, 28.8.00 (PW, CA, JM).

2232 *Aporophyla nigra* (Haworth). Black Rustic. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (DAB, PW, JM, CA); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2254 *Antitype chi* (Linnaeus). Grey Chi. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (DAB, PW, JM, CA).

2270 *Omphaloscelis lunosa* (Haworth). Lunar Underwing. Harris Mausoleum, MV trap (NM336957) 1.9.00 (JM, CA).

2273 *Xanthia togata* (Esper). Pink-Barred Sallow. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Castle rear (NM400995), UV trap, 30.8.00 (DAB, PW, JM, CA); Rose Garden (NM402995), UV trap, 31.8.00; Peat Pool, MV trap (NG395001) 29.8.00 (DAB, PW, CA, JM); Kilmory Glen Streamside Plot (NM338962), UV trap, 28.8.00 (JM, CA, PW); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2274 *X. icteritia* (Hufnagel). Sallow. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; open alder woodland, UV trap (NG394002) 29.8.00 (PW, DAB, CA, JM); Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

2280 *Acronicta leporina* (Linnaeus). Miller. South Side Loch Scresort (NM4198), single larva on alder, 31.8.00 (KB); Kinloch Glen Nature Trail (NG397000), reared, imago emerged 4.6.01 (CA). These confirm an earlier record (Harrison 1955).

2284 *A. psi* (Linnaeus). Grey Dagger. Kilmory (NG3603) 27.8.00, single larva on rowan; Kinloch (NM4099), another larva on rowan; South Side Loch Scresort, larvae on rose and aspen (NM4198) (KB); Larvae, Kinloch Glen Nature Trail (NM3999) 29.8.00, and Kilmory, on hawthorn (NG361038) 27.8.00 (CA).

2289 *A. rumicis* (Linnaeus). Knot Grass. Kilmory (NG3603) 27.8.00, larvae on scabious and rose, and 1.9.00, on bramble; Harris (NM3396), one larva swept, 29.8.00 (KB); Kilmory, larva (NG361038) 28.8.00, and Kinoch, larvae on assorted herbage including *Succisa pratensis*, one pupated, imago emerged 14.6.01 (CA).

2299 *Amphipyra tragopoginis* (Clerck). Mouse Moth. Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA).

2306 *Phlogophora meticulosa* (Linnaeus). Angle Shades. Kilmory (NG3603) 27.8.00, larva beaten from rose; one imago emerged, 16.10.00 (KB).

2321 *Apamea monoglypha* (Hufnagel). Dark Arches. Kinloch Rose Garden (NM402995), UV trap, 31.8.00 (JM, CA); Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, JM, CA, DAB); Kilmory Glen

Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, CA, JM); Harris Tree Plot (NM338962) 1.9.00 (JM, CA); Harris Mausoleum (NM33695) 1.9.00 (JM, CA).

2326 *A. crenata* (Hufnagel). Clouded-Bordered Brindle. Kinloch Castle side, MV trap, 24.8.00 (PW).

2343 *Mesapamea secalis* (Linnaeus). Common Rustic. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; open alder woodland, UV trap (NG394002) 29.8.00 (DAB, PW, JM, CA); Kilmory Dunes, UV trap (NG363037) 28.8.00; Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (JM, CA, PW).

2350 *Chortodes pygmina* (Haworth). Small Wainscot. Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW).

2353 *Luperina testacea* (Denis & Schiffermüller). Flounced Rustic. Kilmory Dunes, UV trap (NG363037) 28.8.00 (CA, JM, PW).

2357 *Amphipoea lucens* (Freyer). Large Ear. Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, JM, CA); Kilmory Dunes, UV trap (NG363037) 28.8.00; Kilmory Glen Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM. CA); Harris Tree Plot (NM338962), UV trap, 1.9.00 (JM, CA); netted near Shamhnan Insir (NG373043) 27.8.00 (JM). Specimens were collected from all of the above localities totalling 21 imagines all of which turned out to be *A. lucens.*

2361 *Hydraecia micacea* (Esper). Rosy Rustic. Kinloch Castle side, MV trap, 24.8.00 (PW); Rose Garden (NM402995), UV trap, 31.8.00 (JM, CA); Kilmory Glen, Stream Plot (NG364010) 28.8.00 (JM, CA, PW).

2367 *Celaena haworthii* (Curtis). Haworth's Minor. Fionchra (NG338004) 1.9.00 (GC); Kinloch Turbine MV trap (NM399994) 30.8.00 (PW, DAB, JM, CA).

2368 *C. leucostigma* (Hübner). Crescent. Kinloch (NM4099) one, 30.8.00 (KB); Kinloch Turbine, MV trap (NM399994) 30.8.00; Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00; open alder woodland, UV trap (NG394002) 29.8.00 (PW, DAB, CA, JM); Kilmory Dunes, UV trap (NG363037) 28.8.00; Kilmory Streamside Tree Plot (NG364010), MV trap, 28.8.00 (PW, JM, CA).

2441 *Autographa gamma* (Linnaeus). Silver Y. Askival (NM3894), one, 28.8.00; Kinloch (NM4099) 30.8.00 (KB); Kinloch Glen Peat Pool, MV trap (NG395001) 29.8.00 (PW, DAB, CA, JM).

2477 *Hypena proboscidalis* (Linnaeus). Snout. Kinloch Castle side, MV trap, 24.8.00 (PW); Rose Garden larva parasitised, 31.8.00 (CA).

ABBREVIATIONS

Moth Traps: MV trap = Mercury Vapour Trap
UV trap = Ultraviolet Trap
* = hitherto unrecorded on Rum
Grid references are indicated in brackets.
Initials of contributors are indicated in brackets at the end of each entry:
The numbering and nomenclature follow the CHECKLIST OF LEPIDOPTERA RECORDED FROM THE BRITISH ISLES. J.D. BRADLEY (1998)

COLEOPTERA

The beetles received a great deal of attention producing no less than 42 previously unrecorded species. Roger and Rosy Key, who had attended the 1990 Rum gathering, produced a substantial amount of new information on the distribution of species already recorded and added 6 new species to the checklist. We were honoured to have R Colin Welch, who had contributed substantially to the 1969 team survey, following this up with additional visits in the 1970s. During the 2000 survey he recorded over 300 species, 33 of which were new to the Rum checklist. Shona Blake concentrated on the Carabidae and added 3 previously unrecorded species. There were also contributions from David Phillips and Keith Bland.

The above figures include the results of pitfall trappings carried out by David Beaumont on Hallival, in the Kilmory Fank, Harris and Guiridil Tree Plots and behind The White House at Kinloch between May and July 2000. Without the initiative he took in setting out and retrieving these traps, the following list would not have been quite so impressive.

Colin Welch's comments on Coleoptera recorded during the survey are as follows:

"The most remarkable outcome of the Coleoptera survey of Rum during the Scottish Entomologists' visit in late August/early September 2000 was the unexpectedly large number of species recorded for the first time from the island. A substantial beetle fauna had already been recorded during extensive surveys over the previous 40 years. By 1974 there were confirmed records of 523 species from Rum (Wormell, 1982), which had increased to 551 by 1999 (Wormell, in prep.). The 2000 survey raised this total to 593 species, an impressive fauna for an island with a limited range of habitats.

The recent programme of re-afforestation north of Kinloch Glen has, as yet, had little or no influence on the coleopterous fauna of Rum. Isolated small experimental tree plots planted in 1959 have proved to be very slowly colonised by woodland species. Only the Kinloch Policy woodlands planted since the mid-nineteenth century support

a true woodland beetle fauna. Four specimens of *Gyrophaena poweri* Crotch were found in *Suillus* fungus during the 2000 survey. This rarely recorded staphylinid was not previously known from Scotland and the most northerly British site was from SE Yorkshire (Welch, 2001). Later, (Welch 2003) *Gyrophaena* from the Hunterian Museum & Art Gallery, Glasgow were checked and found to contain earlier Scottish material collected by Dr Roy Crowson at two Ayrshire localities; Girvan in 1944 and Dalrymple Wood in 1979.

The other surprising discovery resulted from a programme of pitfall trapping carried out by David Beaumont prior to the arrival of the 2000 survey party. A series of traps on the eroded northern slopes of Hallival caught large numbers of adult and larval *Amara quenseli* (Shoen). This nationally scarce carabid has a British distribution restricted to the central Scottish Highlands with the exception of outlying records from Nairn and Rum (Luff, 1998). *A. quenseli* was previously known from a single specimen collected on Hallival summit in June 1963 (Steele & Woodroffe, 1969; Wormell, 1982). An earlier survey in 1962 at the same time of the year as the 2000 survey failed to find this species. It seems probable that it lives deep in sand and gravel deposits only venturing onto the surface at night, thus evading usual methods of hand collecting."

The litter samples send to Gordon Corbet in December 2000 by Kathy Sayer and Malcolm Whitmore also produced no less than 6 staphylinid beetles, one of which, *Atheta volans* (Scriba) (det. R. C. Welch), proved to be a new Rum record.

During 2002 and 2003 a programme of pitfall trapping has been embarked upon by SNH from which, it would seem, only Carabidae, along with spiders, are being investigated.

Colin's comments are, again, appropriate.

"A current programme of pitfall trapping at numerous sites throughout the island, including some at which no beetle collecting has previously been undertaken, can be expected to raise the total species of Rum Coleoptera to over 600 (but only provided all specimens are identified, and not just selected families such as Carabidae)."

Colin Johnston's record of *Atomaria nigripennis* (Kng) from the Kinloch area (1993 Atlas of Atomariinae) is included in the following list as are Carabidae collected by Chris Preston in July 2000.

Carabidae

Cicindela campestris Linnaeus. Harris (NM3395) August 2000 (SB); Harris burn (NM3396) 29.8.00 (KB); Samhnan Insir (NG379043) 27.8.00 (RK).

Cychrus caraboides (Linnaeus). Dibidil track (NM4196) August 2000 (SB); Harris (NM3495); Loch Fiachanis (NM3594); Barkeval summit (NM3797) 30.8.00; Guirdil (RK).

Carabus arvensis (Herbst). Specimens collected on Rum in July 2000 by C. D. Preston (determined and retained by Mark Telfer).

C. glabratus (Paykull). Specimens collected on Rum, July 2000, by C. D. Preston (determined and retained by Mark Telfer); Kinloch Castle woodlands (NM4099) 27.8.00, 28.8.00, 31.8.00 and 1.9.00 (RCW); larva in pitfall trap behind office (D B. det. RCW).

C. granulatus Linnaeus. Harris (NM3395) August 2000 (SB); Guirdil (NG319008) 27 July-30 August, pitfall traps (DB det. RK).

C. nemoralis Mueller. Kinloch (NM4099) pitfall traps, August 2000 (DB det. SB).

C. problematicus Herbst. Hallival (NM3996) below summit, 28.8.00, one under stone; Dibidil 30.8.00, one dead in dry flood refuse in stream above beach (RCW); Askival, 600 m (NM3995) (RCW); Hallival (NM3996) August 2000, pitfall trap (DB det. RK); Barkeval summit (NM3797) 30.8.00 (RK).

Leistus fulvibarbis Dejean. Guirdil Glen Tree Plot, 2, pitfall traps (NG319008) (DB det. RCW).

L. rufescens (Fabricius). Kilmory Fank (NG3603) 2 July-11 August 2000 and 30.8.00 (DB det. RK).

Nebria brevicollis (Fabricius). Hallival, one under stone 1.9.00 and pitfall traps 27 July-28 August 2000, 12 (DB det. RCW); Harris, (NM3395) and (NM3495); Harris Tree Plot; pitfall traps August 2000; Kinloch (NM4099) pitfall traps August 2000 (SB).

N. gyllenhali (Schoenhrr). Hallival (NM392967) pitfall traps 27 July-28 August 2000; adults very common and 5 larvae (DB det RCW.); Hallival, (NM3996) 500 m (SB); Hallival (NM3996), pitfall traps, 25 (DB. det. RK).

N. salina Fairmaire et Laboulbene. Coire Dubh (NM3992), two on silt/gravel beside stream; Harris Tree Plot (NM337962), 4 under pine log on roadside verge outside gate (RCW); Hallival pitfall traps (NM392967) 27 July-28 August 2000 (DB det. RCW); Kilmory Dunes (NG3604) 27.8.00 (RK); Bealach an Oir (NM3895) 28.8.00 (DP); Hallival (NM3996) 28.8.00 (RK); Harris (NM3495) 29.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

Notiophilus aquaticus (Linnaeus). Kilmory Dunes (NG3604) 27.8.00 (RK).

N. biguttatus (Fabricius). Harris Tree Plot (NM337962) 29.8.00, 2, sieving moss on *Lasius flavus* mound; Kinloch Castle woods (NM4099) 1.9.00, one larva sieving moss (RCW); Guirdil Glen (NG319008), one adult and 6 larvae in pitfall traps; Hallival, pitfall trap (NM399967) 1.9.00 and one under stone (DB det. RCW); Kinloch, 4 in pitfall traps behind post office (D. B det. RCW); Hallival (NM3996) 500 m; Kilmory Fank (NG3600), pitfall traps; Harris Tree Plot (NM338962) (DB det SB); Kinloch, near White House (NM4099) 2 July-28 August 2000, common (DB det RK); Hallival (NM3996) 28.8.00; Harris (NM3495) 29.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

N. germinyi Fauvel. Hallival (NM392967), pitfall traps, 27 July-28 August 2000 (DB det. RCW); Askival (NM3995) 27.8.00; Barkeval summit (NM3797) 30.8.00 (RK).
Loricera pilicornis (Fabricius). Coire Dubh (NM3998) 28.8.00 on silt/gravel beside stream (RCW); Guirdil Glen Tree Plot 1.9.00 one larva in pitfall trap; Harris Tree Plot 27 July-31 August 00; Kinloch Castle woodlands 27 July-1 Sept 00, one in pitfall trap behind the White House (DB det RCW); Kilmory Fank Tree Plot (NG3600), pitfall traps; Harris Tree Plot (NM338962), pitfall traps; Kinloch (NM4099) pitfall traps; Kinloch, behind the White House (NM4099), pitfall traps, 2.8.00 (DB det. RK); Loch Fiachanis (NM3594) 29.8.00; Loch Gainmhich (NM3798) 30.8.00 (RK).
Clivina fossor (Linnaeus). Hallival, one under juniper, one under stone (N392967) 1.9.00 (DB.); Harris (NM338962) and Harris Tree Plot (NM338962), pitfall traps August 2000 (DB det SB); Harris (NM3395) (SB); Hallival (NM3797) 30.8.00; Barkeval summit (NM3797) 30.8.00 (RK).
Broscus cephalotes (Linnaeus). Kilmory (NG3603) (SB).
Miscodera arctica (Paykull). Hallival (NM3996) August 2000, pitfall traps (DB det RK). [Nat Scarce]
Petrobus assimilis Chaudoir. Hallival (NM3996) 28.8.00; (RK).
Trechus obtusus Erichson. Coire Dubh (NM3998) 28.8.00, 3 under stones; Hallival at base of summit, 2 sieving moss; Bagh na h-Uamha (NM420971) 1.9.00 sieving *Molinia* litter in sink hole above beach near patch of alders (RCW); Guirdil Glen Tree Plot (NG319008) 27 July-1 September, 2 in pitfall traps; Hallival, in pitfall traps, 27 July-28 August 2000, 9 under juniper, one under stone (NM392967); Harris Tree Plot 27 July-31 August 00 (NM337962), 2 in pitfall traps; Kinloch Castle woodlands (NM4099) 27 July-1 September 00, 4 in pitfall traps behind the White House (DB det RCW); Askival (NM3995) 600 m; Kilmory (NG3504) (SB); Harris Tree Plot (NM338962), pitfall traps and Kinloch (NM4099), pitfall traps (DB det. SB); Hallival (NM3996), 11; behind the White House (NM4099), 7; Kilmory Fank (NG3603) 27 July-30 August 00, pitfall traps; (DB det. RK); Kilmory Dunes (NG3604) 27.8.00; Hallival (NM3996) 29.8.00; Loch Fiachanis (NM3594) and Barkeval summit (NM3797) 30.8.00 (RK).
Bembidion atrocoeruleum Stephens. Coire Dubh (NM3998) 28.8.00, one ♂, one ♀, on silt and gravel beside stream (RCW); Kilmory burn (NG3600) (SB).
B. bipunctatum (Linnaeus). Coire Dubh (NM3998) 28.8.00, running over gravelly area beside stream (RCW); Hallival pitfall traps 27 July-28 August 00 (NM337962), one (DB det RCW), one (RK det RK).
B. lampros (Herbst). Harris Mausoleum (NM3395) 29.8.00, under stones; Kinloch beside the White House; one above beach (RCW).
**B. bruxellense* Wesmael. Hallival (NM3996) 27 July-31 August 00, one (DB det. RK).
B. tetracolum Say. Kilmory Dunes (NM3495) 29.8.00 (RK).
Pterostichus madidus (Fabricius). Harris Mausoleum (NM3395) 29.8.00; Kinloch (NM4099), 2 under stones behind the White House; Port na Caranean (NG424988) 1.9.00, crawling on path (RCW); Harris Tree Plot 27 July-31 August 00, one in pitfall trap; Kinloch Castle woods 27 July-31 August 00, 3 in pitfall traps behind the White House (DB det. RCW); Harris (NM3395) and Dibidil track (NM4098) (SB); Harris Tree Plot (NM338962) and Kinloch (NM4099), pitfall traps (DB det. SB); Harris (NM3495) 29.8.00 (RK).
P. niger (Schaller). Coire Dubh (NM3998) 28.8.00 crawling on path (RCW); Kilmory Fank (NG3600), pitfall traps (DB det. SB); Dibidil track (NM4093) (SB); Guirdil (NG319008), 3 May-August (DB det. RK).
P. melanarius (Illiger). Kilmory Fank (NG3600), pitfall traps, July-August 00; Kinloch, pitfall traps (NM4099) (DB det. SB); Guirdil (NG319008) May-August, 2 (DB det. RK).
P. nigrita (Paykull) sensu stricto. Kilmory (NG3504) (SB); Kinloch, pitfall traps (NM4099); Harris Tree Plot (NM338962), pitfall traps (DB det. SB); Kinloch (NM4099) 27.8.00, one ♀, in seaweed on shore; Harris Tree Plot (NM337962) 29.8.00, one dead sieving moss on *Lassius flavus* mound; Harris Mausoleum (NM3395) 29.8.00, under stone on grassy lawn above beach; Dibidil (NM3992) 30.8.00, one ♂, one ♀, sieving moss below bothy; Kinloch Castle woods (NM4099) 31.8.00, in compost heap in vegetable garden (RCW); behind the White House, pitfall traps (NM4099) 27 July-1 September (DB det. RCW).
P. strenuus (Panzer). Dibidil (NM3992) 30.8.00, 4, sieving moss below bothy (RCW); Harris Tree Plot, pitfall traps (NM338962) (DB det. SB).
Abax parallelepipedus (Piller & Mitterpacher). Harris Tree Plot 27 July-31 August 2000, pitfall traps (NM337962); pitfall traps behind the White House, Kinloch (NM402992) 27 July-1 September 2000 (DB det. RCW); Kilmory Fank (NG3600), pitfall traps (DB det. SB); Barkeval summit (NM3797) 30.8.00 (RK); Guirdil (NG319008) (May 2000-August 2000), pitfall traps, 3 (DB det. RK).
Calathus fuscipes (Goeze). Harris Mausoleum (NM3395), one under stone on grassy lawn above beach 29.8.00; Harris, east of boulder beach (NM3495) 29.8.00, one live, one dead, under stones (RCW); Harris (NM3395) (SB); Kilmory Dunes (NG3604) 27.8.00; Harris (NM3495) 29.8.00; Loch Fiachanis (NM3594) 29.8.00 (RK).
C. melanocephalus (Linnaeus). Kilmory Bay (NG3603) 27.8.00, 2 under drfitwood on beach. Harris east of boulder beach, 29.8.00 (NM3495) two under stones (RCW); Harris (NM395); Kilmory (NG3603 and 3504) (SB); Hallival (NM3996) 28.8.00, ♂; Harris (NM3495) 29.8.00 (RK).

C. mollis (Marsham). Kilmory Bay (NG3604) 27.8.00, one ♂ under driftwood on beach (RCW); Kilmory (NG3603) (SB); Kilmory Dunes (NG3604) 27.8.00 (RK).
Olisthopus rotundatus (Paykull). Hallival pitfall traps, 27 July-28 August 2000 (NM392967), 30+ and 2 under juniper (DB det. RCW); Coire Dubh path (NM3999); Allt nam Ba, 400 m (SB); Hallival (NM3996), 26 July-28 August 2000, pitfall traps, 11 (DB det. RK); Hallival (NM3996) 28.8.00; Harris (NM3495) 29.8.00; Barkeval summit (NM3797) 30.8.00 (RK).
Agonum albipes (Fabricius). Port na Caranean (NG424988), 2 in rotten seaweed at top of gully (RCW); Askival 450 m (NM3995) (SB); Kilmory Dunes (NG3604) 27.8.00; Harris (NM3495) 29.8.00; Loch Fiachanis (NM3594) 29.8.00 (RK).
A. gracile Sturm. Harris (NM3395) (SB).
A muelleri (Herbst). Harris (NM3395) (SB); Harris Tree Plot (NM337962) 29.8.00, under logs by gate; Harris Mausoleum (NM3395) 29.8.00, under stones; Kinloch woods (NM4099), beside the White House, 4 and one above beach (RCW).
Amara aenea (Degeer). Hallival (NM3996) 27 July-31 August 2000, pitfall trap, one (DB det. RK).
A. quenseli (Schoen). Hallival, pitfall traps (NM392967) 27 July-28 August 2000, adults abundant and 5 larvae (DB det RCW), also (DB det. SB) and 73 adults (DB det. RK); Hallival 28.8.00, 4 ♂♂, 5 ♀♀ (NM3996); (RK).
Harpalus latus (Linnaeus). Barkeval summit (NM3797) 30.8.00 (RK).
H. rufipes (Degeer). Kinloch Castle woods (NM4099), sieving compost heap, 31.8.00 (RCW).
Trichocellus cognatus (Gyllenhal). Hallival (NM3996) 28.8.00 (RK).
Cymindis vaporariorum (Linnaeus). Hallival, 27 July-28 August 2000, one in pitfall trap (DB det. RCW); Barkeval summit (NM3797) 30.8.00 (RK).

Dytiscidae

**Nebrioporus depressus elegans* (Panzer) (= *Potamonectes depressus elegans* (Panzer). Loch Fiachanis (NM3594) 29.8.00 (RK).
Hydroporus longulus Mulsant. Coire Dubh (NM3998), one ♀ in pool in gravel area beside stream, 28.8.00 (RCW).
Agabus bipustulatus (Linnaeus). Coire Dubh (NM3998), one ♀ in small stagnant pool, 28.8.00 (RCW); Loch Gainmhich (NM3798) 30.8.00 (RK).
A. guttatus (Paykull). Coire Dubh (NM3897) 28.8.00 (RK).

Gyrinidae

Gyrinus substriatus Stephens. Loch Gainmhich (NM3798) 30.8.00 (RK).

Hydrophilidae

Helophorus flavipes (Fabricius). Harris east of boulder beach (NM3495) 29.8.00, one ♀ in rotting seaweed on boulder beach (RCW).
Cercyon atomarius (Fabricius). Kilmory Dunes (NG3604) 27.8.00 (RK).
C. depressus Stephens. Kilmory Bay (NG3603) 27.8.00, one in dead gull on beach (RCW).
C. haemorrhoidalis (Fabricius). Kilmory Bay (NG3603) and (NG3604), single adults in horse dung (RCW); Guirdil (NG319008), May-August 2000, pitfall trap (DB det. RK).
C. melanocephalus (Linnaeus). Kilmory Bay (NG3603) and (NG3604), 23 in horse dung and 4 in deer dung; Hallival shearwater greens, 6 in deer dung on path; Harris Mausoleum (NM3395) 29.8.00, 14 in cattle dung; Harris east of boulder beach (NM3495) 29.8.00, in deer dung; Dibidil (NM3992) 30.8.00, 2 in deer dung on lawn above beach (RCW). Kilmory Dunes (NG3604) 27.8.00; Hallival (NM3996) 28.8.00 (RK).
Megasternum obscurum (Marsham). Kilmory Cottage (NG3503) 27.8.00, 2 in deer skull; Kinloch Castle woods (NM4099) 31.8.00, sieving compost heap; 1.9.00, 14, sieving moss (RCW); Guirdil Glen Tree Plot, July-1 September 2000, 13 in pitfall traps; Harris Plot (NM337962), 2 in pitfall traps 27 July-31 August 2000; Kinloch, behind the White House (NM4099), one in pitfall trap (DB det. RCW), also 11 in pitfall traps (NM4099) (DB det. RK); Kilmory Fank (NG3603), pitfall traps, 18, 2 July-11 August 2000 and one, 30.8.00; Kilmory Dunes (NG3604) 27.8.00, 17, pitfall traps, May-August 2000 (DB det. RK).
Anacaena globulus (Paykull). Kinloch, behind the White House (NM4099) 27 July-30 August 2000, 9, pitfall traps (DB det RK) and 5 (DB det. RCW); Guirdil Glen (NG319008), pitfall traps in Tree Plot July-1 September 2000; Harris Tree Plot (NM337962) 27 July-31 August 2000, 14 in pitfall traps (DB det. RCW); Dibidil (NM3992), 2, sieving moss in stream trickle, 30.8.00; Kinloch Castle woodland (NM4099) 1.9.00, one ♀ sieving litter under rotten fungi near generator hut, also 4 sieving moss (RCW). Kilmory Fank (NG3603) 2 July-30 August; Guirdil (NG3603) May-August 2000; (DB det. RK); Kinloch woods (NM401997) December 2000, from leaf litter/top soil, one (K. Sayer det. RCW).

Ptiliidae

Ptenidium punctatum (Gyllenhal). Harris east of boulder beach (NM3495) 29.8.00, in rotting seaweed (RCW).
Nanoptilium kunzei (Heer). Dibidil (NM3992) one ♀ in deer dung on lawn above beach. Kinloch Castle woodlands (NM4099), one ♂ in rotten fungus near generator hut, 2 ♂♂ in fungi behind the White House 31.8.00 (RCW).

**Acrotrichis cognata* (Matthews). Kilmory Bay east (NG3604), one ♀ in horse dung; Kilmory Fank Tree Plot (NG 362008) 27.8.00, 3 ♀♀ sieving litter under oak and pine. Kinloch Castle woodlands (NM4099) 31.8.00, 2 ♀♀ in rotten fungus near Turbine House (RCW).

A. grandicollis (Mannerheim). Kilmory Bay east (NG 3604) 27.8.00, 30 ♂♂ and ♀♀ in horse dung; Harris Mausoleum (NM3395) 29.8.00, in cattle dung; Dibidil (NM3992) 30.8.00, 2 in deer dung on lawn above beach (RCW).

A. intermedia (Gillmeister). Kilmory Fank Tree Plot (NG362008) 27.8.00, common sieving litter under oak and pine; Kinloch Castle woodlands (NM4099) 28.8.00, 4 in *Suillus* beside path near generator house; Harris Tree Plot (NM337962) 29.8.00, 2 ♀♀ sieving moss on *Lasius flavus* mound; Kinloch Castle woodlands (NM4099) 1.9.00, 4 sieving moss; (RCW). Guirdil Glen (NG 319008) May-August 2000, 12 in pitfall traps; (DB det. RCW); Kinloch (NM401997) December, 6 from deciduous leaf litter/topsoil; (K. Sayer det. RCW).

A. rugulosa Rosskothen. Kilmory Fank Tree Plot (NG362008) 27.8.00, 3 ♀♀ in litter under oak and Scots pine; Harris Tree Plot (NM337962) 29.8.00, 4 ♂♂, 5 ♀♀, sieving moss on *Lasius flavus* mound; Harris Mausoleum (NM3495) 29.8.00, one ♀ in cattle dung; Kinloch Farm barns (NM4099) 31.8.00, 5 ♂♂, 2 ♀♀, sieving hay (RCW); Kinloch woodlands (NM401997) December 2000, 6 from leaf litter and topsoil (K. Sayer det. RCW).

**A. silvatica* Rosskothen. Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♀ in litter under oak and pine; (RCW); 2000.

Leiodidae

Nargus velox (Spence). Kinloch Castle woodlands (NM4099) 1.9.00, sieving litter under rotten fungi near Turbine House, 3 ♂♂, one ♀ sieving moss; (RCW); Kilmory Fank (NG3603), pitfall traps, 2 July-11 August, one (DB det. RK).

**Catops fuliginosus* (Erichson). Kinloch Castle woodlands (NM4099) 1.9.00, one ♂, one ♀, sieving moss (RCW).

C. tristis (Panzer). Guirdil (NG319008), pitfall traps May-August (DB det RK).

Silphidae

Aclypea opaca (Linnaeus). Kinloch Castle woods (NM4099), one larva sieving moss (RCW).

Silpha atrata Linnaeus. Port na Caranean (NG424988) 1.9.00, under plank on beach. Kinloch Castle woods (NM4099) 1.9.00, one larva sieving moss (RCW); Kinloch behind the White House (NM4099), pitfall traps 2 July-August 2000, 2; Guirdil, pitfall traps, May-August 2000, 3 (DB det RK).

Scydmaenidae

Stenichnus collaris (Müller & Kanza). Kinloch woods (NM401997) December 2000, one from deciduous leaf litter/topsoil (K. Sayer det. RCW).

Staphylinidae

Megarthrus depressus (Paykull). Kilmory Bay east (NG3604) 27.8.00, 6 in horse dung; Harris Mausoleum (NM3395) 29.8.00, 5 in cattle dung (RCW).

M. sinuatocollis (Boisduval & Lacordaire). Kilmory Fank Tree Plot (NG 362008), 2 ♂♂ in *Suillus* and other fungi, 27.8.00 (RCW); Kinloch Castle woods (NM4099) 2 July-1 September 2000, pitfall traps behind the White House (DB det. RCW), also same locality, 4 (DB det. RK).

Proteinus brachypterus (Fabricius). Kilmory Fank Tree Plot (NG362008) 27.8.00, 14 in *Suillus* and other fungi; Kinloch Castle woodlands (NM4099), 6 31.8.00; one 1.9.00 in rotten fungus near Turbine House and common in fungi behind the White House (RCW).

Olophrum fuscum (Gravenhorst). Coire Dubh (NM3998) 28.8.00, 2 sieving flood refuse; Kinloch Castle woodlands 31.8.00 sieving compost heap; Allt Mor na h-Uamha (NM404983) 1.9.00, sieving *Molinia* litter washed onto path; Bagh na h-Uamha (NM420971) 1.9.00, 2 sieving *Molinia* litter in sink hole above beach (RCW); Guirdil (NG319008), pitfall traps May-August, one (DB det. RK).

**O. piceum* (Gyllenhal). Guirdil (NG319008), pitfall traps, May-August, one (DB det. RK).

Arpedium brachypterum (Gyllenhal). Hallival (NM392967), pitfall traps, 27 July-28 August 2000, 2 (DB det RCW); also one (DB det. RK).

Lesteva heeri Fauvel. Allt Mor na-h-Uamha (NM404983) and (NM 405979), 3 sieving *Molinia* litter washed onto path; Bagh na h-Uamha (NM420971), 4 sieving *Molinia* litter in sink hole above beach, 1.9.00; Kinloch Castle woodlands (NM4099) 1.9.00, sieving litter under rotten fungi near Turbine House (RCW); Guirdil Tree Plot, pitfall traps, May-August 2000, one (DB det. RCW).

Geodromicus longipes (Mannerheim). Hallival (NM392967), pitfall traps, 27 July-28 August 2000, 2 (DB det RCW) and one, same locality, also in pitfall (DB det. RK).

G. nigrita (Müller). Hallival (NM3996) 27 July-28 August, 3 in pitfall traps (DB det. RK).

**Omalium excavatum* Stephens. Guirdil Glen Tree Plot, pitfall traps, May-August (NG319008), one ♀ (DB det. RCW).

O. laeviusculum Gyllenhal. Kinloch Castle woodlands (NM4099) 27.8.00, one in seaweed on shore; Kilmory Bay (NG3603) 27.8.00, 17 in seaweed; Harris east of boulder beach (NM3495) 29.8.00, 18 in seaweed; Dibidil

(NM3992) 30.8.00, 2 in seaweed on boulder beach; Bagh na h-Uamha (NM420971), 1.9.00, 10 in seaweed at top of gully; Port na Caranean (NG424988), 5 in seaweed (RCW); also same locality 30.8.00 in seaweed (RK).
O. rivulare (Paykull). Guirdil Glen Tree Plot pitfall traps (NG319008) May-September 2000, one ♂; Kinloch Castle woodlands (NM4099), pitfall traps behind the White House, one (DB det. RCW) and 3 (DB det. RK); Kilmory Fank (NG3603) 2 July-11 August 2000, 2 in pitfall traps (DB det. RK).
Xylodromus concinnus (Marsham). Kinloch Farm barns (NM4099) 31.8.00, 19 sieving hay (RCW).
**Carpelimus bilineatus* Stephens. Dibidil (NM3992) 30.8.00, one ♂ in grassy flood refuse washed onto top of beach (RCW).
Anotylus maritimus Thomson. Kilmory Bay (NG3603) 27.8.00, 10 in seaweed, one under driftwood on beach (RCW).
Oxytelus laqueatus (Marsham). Kilmory Bay east (NG3604) 27.8.00, 21 in horse dung; Hallival shearwater greens (NM3997) 28.8.00, 2 in deer dung; Coire Dubh (NM3998) 28.8.00, in deer dung on path; Harris Mausoleum (NM3395) 29.8.00, 7 in cattle dung; Dibidil (NM3992) 30.8.00, 3 in deer dung on lawn above beach (RCW); Barkeval summit (NM3797) 30.8.00 (RK).
Stenus brunnipes Stephens. Hallival shearwater greens (NM3997) 28.8.00, one ♂ sieving moss; Dibidil (NM3992) 30.8.00, 1 ♂ in dry flood refuse in stream valley above beach (RCW); Guirdil (NG319008), pitfall traps, May-August 2000, one (DB det. RK).
S. clavicornis (Scopoli). Hallival shearwater greens (NM3997) 28.8.00, one ♂ sieving moss (RCW).
S. fulvicornis Stephens. Hallival shearwater greens (NM3997) 28.8.00, one ♀ sieving moss (RCW).
S. impressus Germar. Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂ in *Suillus*. Kinloch Castle woodlands (NM4099) 27.8.00, one ♀ sweeping path in woodland; Coire Dubh (NM3998) 28.8.00, sieving flood refuse; Dibidil (NM3992) 30.8.00, sieving moss under *Suillus* by track to pier; Bagh na h-Uamha (NM420971) 1.9.00, one ♂ sweeping above beach; Port na Caranean (NG424988) 1.9.00, one ♀ sweeping *Armeria* etc (RCW); Kinloch Castle woodlands (NM4099) 27 July-1 September 2000, pitfall traps behind the White House (DB det. RCW); Guirdil (NG319008) May-August 2000, pitfall traps, one (DB det. RK).
S. nitidiusculus Stephens. Coire Dubh (NM3998) 28.8.00, one ♂ in flood litter (RCW).
Lathrobium brunnipes (Fabricius). Dibidil (NM3992) 30.8.00, one ♀ sieving moss in stream trickle; Kinloch Castle woodlands (NM4099) 1.9.00, sieving litter under rotten fungi near Turbine House (RCW).
L. fulvipenne (Gravenhorst). Bagh na h-Uamha (NM420971) 1.9.00, one ♂ sieving *Molinia* litter in sink hole above beach (RCW).
L. terminatum Gravenhorst. Allt Mor na h-Uamha (NM404983) and (NM405979) 1.9.00, one ♂ sieving *Molinia* litter wash onto path (RCW).
Othius angustus Stephens. Hallival shearwater greens (NM3996) 28.8.00, 2 sieving moss (RCW).
O. punctulatus (Goeze). Kinloch Castle woodlands (NM4099) 1.9.00, 3 sieving litter under rotten fungi near Turbine House (RCW); Guirdil Glen May-1 September, pitfall traps, 3 adults and one larva (DB det.RCW).
Xantholinus linearis (Olivier). Kilmory Cottage (NG3503) 27.8.00, under stone; Kilmory Bay (NG3603) 27.8.00, under driftwood on beach (RCW); Harris (NM3495) 29.8.00 (RK).
**X. longiventris* Heer. Harris (NM3495) 29.8.00 (RK).
Philonthus spp. Kinloch Castle woodlands (NM4099), 8 indet. larvae sieving moss (RCW); Guirdil Glen (NG319008), pitfall traps, May-1 September, 2 larvae (DB det. RCW).
P. cognatus Stephens. Kinloch Castle woodlands (NM4099) 31.8.00, one ♂ sieving compost heap (RCW).
P. fimetarius (Gravenhorst). Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂ in *Suillus*; Kinloch Castle woodlands (NM4099) 31.8.00, one ♀ sieving compost heap; Kinloch Castle woodlands (NM4099) 31.8.00 and 1.9.00, in rotten fungi and sieving litter under fungi near Turbine House (RCW); Kinloch behind the White House (NM4099), pitfall traps, 2 July-August, 2 (DB det .RK).
P. laminatus (Creutzer). Guirdil Glen (NG319008) May-1 September 2000, one ♀ in pitfall traps (DB det RCW); Harris (NM3495) 29.8.00 (RK).
**P. nigrita* (Gravenhorst). Allt Mor na h-Uamha (NM405979) 1.9.00, one ♀ sieving *Molinia* litter washed onto path (RCW).
P. politus (Linnaeus). Dibidil (NM3992) 30.8.00, one ♀ in rotten seaweed (RCW).
P. sordidus (Gravenhorst). Kinloch Castle woodlands (NM4099) 27.8.00, grass mowings behind Castle (RCW).
P. splendens (Fabricius). Kinloch Castle woodlands (NM4099) 27.8.00, grass mowings behind Castle (RCW).
P. succicola Thomson. Kinloch Castle woodlands (NM4099) 27.8.00, 2 ♀♀ in seaweed on shore; Kilmory Cottage (NG3503) 27.8.00, one ♀ sweeping turf; Kilmory Fank Tree Plot (NG 362008) 27.8.00, one in *Suillus* (RCW).
P. tenuicornis Mulsant et Rey. Kinloch Castle woodlands (NM4099) 31.8.00, one ♂ sieving compost heap (RCW); Guirdil Glen Tree Plot (NG319008) May-1 September, 2 ♂♂, 4 ♀♀ in pitfall traps (DB det. RCW).
P. varians (Paykull). Kilmory Bay (NG3603) 27.8.00, 3 ♂♂, one ♀ in horse dung; Kilmory Bay east (NG3604) 27.8.00, one ♂, 5 ♀♀ in horse dung; Harris Mausoleum (NM3395) 29.8.00, in cattle dung (RCW).

P. varius (Gyllenhal). Kilmory Bay (NG3603) 27.8.00, one ♂, 3 ♀♀ in horse dung; Kilmory (NG3604) 27.8.0-0, one ♀ in horse dung; Harris Tree Plot (NM337962) 29.8.00, under logs by gate (RCW); Harris (NM3495) 29.8.00 (RK).
Gabrius pennatus Sharp. Kilmory Bay (NG3603) 27.8.00, one ♂ in seaweed (RCW).
G. trossulus (von Nord). Dibidil (NM3992) 30.8.00, one ♂ sieving moss below bothy (RCW).
Cafius xantholoma (Gravenhorst). Kilmory Bay (NG3603) 27.8.00, 14 in seaweed; Harris east of boulder beach (NM3495) 29.8.00, 3 adults, one larva, in seaweed on boulder beach (RCW).
Staphylinus aeneocephalus De Geer. Dibidil (NM3992) 30.8.00, under stone beside bothy (RCW) and 28.8.00 (RK); Hallival (NM3996) 28.8.00 (RK); Guirdil (NG319008) pitfall traps, May-August, one (DB det. RK).
S. erythropterus Linnaeus. Guirdil (NG319008), pitfall traps, May-August, one (DB det RK).
Creophilus maxillosus (Linnaeus). Kilmory Bay (NG3603) 27.8.00, in seaweed; Kinloch Castle woodlands (NM4099) 31.8.00, in light trap in rose garden (RCW); Kilmory Dunes (NG3604) 27.8.00; Kinloch, field in front of Castle (NM4099) 30.8.00 (RK).
Quedius boopoides Munster. Hallival shearwater greens (NM3997) 28.8.00, 3 ♀♀ sieving moss (RCW); Guirdil (NG319008), pitfall traps, May-August, one ♂ (DB det. RK).
Q. boops (Gravenhorst). Barkeval summit (NM3797) 30.8.00 (RK).
Q. curtipennis Bernhauer. Kinloch Castle woodlands (NM4099) 1.9.00, 8 sieving litter under rotten fungi near Turbine House (RCW); Guirdil Glen (NG319008), pitfall traps, May-August 2000, one ♂, one ♀; Harris Tree Plot (NM337962), one ♂ in pitfall traps (DB det. RCW); Behind the White House at Kinloch (NM4099) 2 July-11 August 2000, pitfall traps, one; Guirdil (NG319008) May-August, pitfall traps, 7 (DB det RK).
Q. nigriceps Kraatz. Dibidil (NM3992) 30.8.00, 11 in grassy flood refuse washed onto beach (RCW).
Lordithon thoracicus (Fabricius). Kilmory Fank Tree Plot (NG362008) 27.8.00, 24 in *Suillus* and other fungi; Kinloch castle woodlands (NM4099), common in *Suillus* beside path near Turbine House; 31.8.00 9 in fungi behind the White House; 1.9.00, 4 sieving litter under rotten fungi near Turbine House (RCW); Kilmory Fank (NG3603), pitfall traps, 15 (DB det. RK); Harris (NM3495) 29.8.00 (RK); Kilmory Fank (NG3603) July-August, 5 (DB det. RK).
**Tachyporus dispar* (Paykull). Kilmory Cottage (NG3503) 27.8.00, 2 ♀♀ sweeping turf; Harris Tree Plot (NM337962) 29.8.00, one ♂, one ♀, sieving moss on *Lasius flavus* mound; Dibidil (NM3992) 30.8.00, under stone beside bothy (RCW).
T. nitidulus (Fabricius). Hallival (NM392967) 27 July-28 August 2000, pitfall traps, one ♀ (DB det. RCW).
Tachinus elongatus Gyllenhal. Guirdil (NG319008), pitfall traps, May-August, one (DB det. RK).
T. laticollis Gravenhorst. Kinloch Castle woodlands (NM4099), 4 sieving compost heaps, 31.8.00 and 20 sieving litter under rotten fungi near Turbine House (RCW); Kinloch (NM4099), behind the White House, 13 in pitfall traps; Kilmory Fank (NG3603) 2 July-11 August, 6 in pitfall traps (DB det. RK).
T. marginellus (Fabricius). Kilmory Fank Tree Plot (NG362008) 27.8.00, 5 in *Suillus* and other fungi; Kinloch Castle woodlands (NM4099) 28.8.00, 3 in *Suillus* beside path near Turbine House; Dibidil (NM3992) 30.8.00, in deer dung on lawn above beach; Kinloch Castle woodlands (NM4099), on old bone near the White House, 1.9.00 and 4 sieving litter under rotten fungi near Turbine House (RCW); Guirdil Glen (NG319008) May-August, 2 in pitfall traps; Harris Tree Plot ,27 July-31 August, 2 in pitfall traps; Kinloch, behind the White House, 27 July-1 September, 2 in pitfall traps (DB det. RCW); Kilmory Fank Tree Plot (NG3603), pitfall traps, 2 July-11 August, 4 (DB det. RK); Hallival (NM3996) 28.8.00 (RK); Guirdil (NG319008), pitfall traps, May-August 2000, 2 (DB det. RK). Kinloch (NM401997) December 2000, one from deciduous leaf litter and topsoil (K. Sayer det. RCW).
T. pallipes Gravenhorst. Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂, one ♀ in *Sulius* and other fungi (RCW); Kilmory Fank (NG3603), pitfall traps, 2 July-11 August, 2 (DB det. RK).
T. proximus Kraatz. Kinloch Castle woodlands (NM4099) 31.8.00, in rotten fungi near Turbine House (RCW).
T. signatus Gravenhorst. Kinloch (NM4099) 27.8.00, 4 in seaweed on shore 31.8.00, 2 sieving compost heap; 31.8.00, 47 sieving litter under rotten fungi near geneator house and 3 larvae sieving moss; Port na Caranean (NM424988) 1.9.00, in seaweed (RCW); Guirdil Glen (NG319008), pitfall traps, May-August, 14 adults and 3 larvae; Harris Tree Plot (NM337962) 27 July-31 August, 4 adults and one larva in pitfall traps; Kinloch Castle woodlands (NM4099) 27 July–1 September, 9 adults and 3 larvae in pitfall traps behind the White House (DB det RCW); Kinloch, behind the White House (NM4099), pitfall traps, 2 July 2000, 171 and 2 August, 45 (DB det. RK); Kilmory Fank (NG3603), pitfall traps, 16 and 30 August, 3; Guirdil (NG319008) May-August, pitfall traps, 49 (DB det. RK); Kinloch (NM401997) December, from deciduous leaf litter and topsoil, one (K.Sayer det. RCW).
**Gymnusa brevicollis* (Matthews). Allt Mor na h-Uamha (NM405979) 1.9.00, one ♂, 2 ♀♀, sieving *Molinia* litter washed onto path (RCW).
Myllaena brevicornis (Paykull). Coire Dubh (NM3998) 28.8.00, one ♀ sieving flood refuse; Dibidil (NM3992) 30.8.0, 3 ♂♂ sieving moss below bothy; Bagh na Uamha (NM420971) 1.9.00, one ♂, 5 ♀♀, sieving *Molinia* litter in sink hole above beach (RCW).

**M. kraatzi* Sharp. Allt Mor na h-Uamha (NM404983) and (NM405979) 1.9.00, sieving *Molinia* litter washed onto path; Bagh na h-Uamha (NM420971), one sieving *Molinia* litter in sink hole above beach (RCW).
**M. minuta* (Gravenhorst). Dibidil (NM3992) 30.8.00, one ♂, one ♀, sieving moss in stream trickle (RCW).
**Gyrophaena affinis* Mannerheim. Kinloch Castle woodlands (NM4099), one ♂ sieving litter under rotten fungi near Turbine House, 1.9.00 (RCW).
**G. poweri* Crotch. Kinloch Castle woodlands (NM4099), one ♂, 3 ♀♀ in *Suillus* beside path near Turbine House (RCW).
Phytosus balticus Kraatz. Kilmory Bay (NG3604), 3 in seaweed, one under driftwood on beach, 27.8.00 (RCW).
Leptusa fumida Kraatz. Kinloch Castle woodlands (NM4099), one ♂, 4 ♀♀, in *Piptoporus betulinus* on dead standing birch, one under bark of cut pine stump, 31.8.00 (RCW).
L. ruficollis (Erichson). Kinloch Castle woodlands (NM4099), in *Piptoporus betulinus* on dead standing birch, 31.8.00 (RCW).
Autalia impressa Olivier. Kilmory Fank Tree Plot, common in *Suillus* and other fungi, 27.8.00; Kinloch Castle woodlands (NM4099), 3 in *Suillus* and other rotten fungi beside path near Turbine House, 28.8.00 and 31.8.00; 14 in fungi behind the White House, 1.9.00 (RCW). Kilmory Fank Tree Plot (NG3603) 2 July-11 August 2000, 3; and 30.8.00, one (DB det. RK).
A. rivularis (Gravenhorst). Harris Mausoleum (NM3395) 29.8.00, 3 in cattle dung (RCW).
**Falagria thoracica* Stephens. Harris Tree Plot (NM337962) 29.8.00, one sieving moss on *Lasius flavus* mound (RCW).
**Aloconota* (s. str.) *gregaria* (Erichson). Hallival, pitfall traps (NM392967) 27.7.00-28.8.00, one ♂ in pitfall trap (DB det. RCW).
Amischa bifoveolata (Mannerheim) (- *A. cavifrons* (Sharp)). Harris Mausoleum (NM3395) 29.8.00, one ♀ under stone on grassy lawn above beach; Dibidil (NM3992) 30.8.00, one ♀ under stone beside bothy; Hallival pitfall traps (NM392967) 27 July-28 August 2000, one ♂, one ♀, in pitfall trap (RCW).
Nehemitropia sordida (Marsham). Kinloch (NM4099) 31.8.00, one ♂ sieving compost heap (RCW).
Geostiba circellaris (Gravenhorst). Kinloch Castle woodlands (NM4099) 1.9.00, sieving litter under rotten fungi near Turbine House (RCW).
**Atheta* (*Philhygra*) *volans* (Scriba). Kinloch Castle woodlands (NM401997), 17 from deciduous leaf litter and topsoil, December 2000 (K.Sayer det. RCW).
A. (*Anopleta*) *corvina* (Thomson). Kinloch Castle woodlands (NM4099) 31.8.00, one ♂, in fungi behind the White House (RCW).
A. (*Microdota*) *amicula* (Stephens) Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂, in *Suillus;* Kinloch Castle woodlands (NM4099) 28.8.00, one ♂, one ♀, in *Suillus* beside path near Turbine House; Hallival (NM392967) 1.9.00, one ♀, under stone (DB det. RCW).
A. (*Lohse Grp. II*) *cadaverina* (Brisout). Kinloch Fank Tree Plot (NG362008) 1.8.00, 4 ♂♂, 3 ♀♀, in *Sulius* and other fungi (RCW).
A. (*Lohse Grp. II*) *gagatina* (Baudi) Kinloch Castle woodlands (NM4099) 28.8.00, 3 ♂♂, one ♀, in *Sulius* beside path near Turbine House (RCW).
A. (*Lohse Grp. II*) *picipes* (Thomson). Kinloch Castle woodlands, 31.8.00, one ♀, in *Piptoporus betulinus* on dead standing birch (RCW).
A. (*Lohse Grp. II*) *tibialis* (Heer). Hallival below summit (NM3996) 28.8.00, one ♀, under stone; Hallival pitfall traps (NM392967) 27 July-28 August 2000, common (RCW).
A. (*Mocyta*) *fungi* (Gravenhorst). Kinloch Castle woodlands (NM4099) 27.8.00, sweeping road verge; Kinloch Farm barn (NM4099) 31.8.00, sieving hay; Guirdil Glen Tree Plot (NG319008) (RCW). Pitfall traps, May-August 2000, one in pitfall (DB det. RCW).
A. (*s. str.*) *aquatica* (Thomson). Kilmory Fank Tree Plot (NG362008) 27.8.00, 2 ♂♂, 4 ♀♀, in *Suillus* and other fungi; Dibidil (NM3992) 30.8.00, 5 ♀♀, in rotten seaweed; Bagh na h-Uamha (NM420971) 1.9.00, 2 ♂♂, one ♀, in rotten seaweed at top of gully, one ♀, sweeping birch above gorge to beach (RCW); Guirdil Glen Tree Plot (NG319008), pitfall traps, May-August 2000, one ♀, in pitfall; Kinloch Castle woodlands (NM4099) 27 July-1 September, pitfall traps behind the White House, 2 ♂♂, 4 ♀♀ (DB det. RCW).
**A.* (*s. str.*) *brunneipennis* (Thomson). Harris Tree Plot (NM337962), pitfall traps, 27 July-31 August, one ♀, in pitfall (DB det. RCW).
A (*s. str*) *castanoptera* (Mannerheim). Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂, one ♀, in *Suillus* and other fungi; Kinloch Castle woodlands (NM4099) 28.8.00, 2 ♂♂, one ♀, in *Suillus* beside path near Turbine House; Kinloch Castle woodlands (NM4099), one ♂, one ♀, in fungi behind the White House (RCW).
A. (*s. str.*) *pertyi* (Heer). Kinloch Castle woodlands (NM4009) 28.8.00, one ♂ in *Suillus* beside path near generator hut, also 2 ♂♂, one ♀, in rotten fungi (RCW); Harris Tree Plot (NM337962), pitfall traps, 1 ♀, 29.8.00; Kinloch Castle woodlands (NM4099), pitfall traps behind the White House; 27 July-1 September, 1 ♂ (DB det. RCW).

A. (*Lohse Grp. I*) *crassicornis* (Fabricius). Kilmory Fank Tree Plot (NG362008) 27.8.00, 1 ♀ in *Sulius*; Kinloch Castle woodlands (NM4099), 1 ♂ in *Sulius* beside path near Turbine House, 31.8.00; 1 ♂, 5 ♀♀, in fungi behind the White House and 1 ♂, 1 ♀, in *Piptoporus betulinus* on dead standing birch (RCW).
**A.* (*Lohse Grp. I*) *coriaria* (Kraatz). Kinloch Farm barns, 31.8.00, one ♂, 1 ♀, sieving hay (RCW).
A. (*Lohse Grp. I*) *laticollis* (Stephens). Kinloch Castle woodlands (NM4099), one sieving compost heap (RCW).
A. (*Dimetrota*) *atramentaria* (Gyllenhal). Kilmory Bay (NG3603) 27.8.00, one ♂ in dead gull on beach, 15 in deer dung; Kilmory Bay (NG3603) and Kilmory Bay east (NG3604) 27.8.00, abundant in horse dung; Hallival shearwater greens (NM3997) 28.8.00, common in deer dung; Coire Dubh (NM3998) 28.8.00, common in deeer dung on path; Harris Mausoleum (NM3395) 29.8.00, common in cattle dung; Harris east of boulder beach (NM3495) 29.8.00, 4 ♂♂, 3 ♀♀, in deer dung; Dibidil (NM3992) 30.8.00, 3 ♀♀ in deer dung on lawn above beach (RCW).
A. (*Dimetrota*) *cinnamoptera* (Thomson). Kilmory Fank Tree Plot (NG362008) 27.8.00, one ♂ in *Suillus*; Hallival shearwater greens (NM3997) 28.8.00, 2 ♂♂ in deer dung; Coire Dubh (NM3998) 28.8.00, one ♂ in deer dung on path; Dibidal (NM3992) 30.8.00, one ♂, 1 ♀, in deer dung on lawn above beach; Bagh na h-Uamha (NM420971) 1.9.00, one ♂ in rotten seaweed at top of gully (RCW).
A. (*Dimetrota*) *ischnocera* Thomson. Kilmory Bay east (NG3604) 27.8.00, 4 ♂♂, 7 ♀♀, in horse dung; Harris east of boulder beach (NM3495) 29.8.00, one ♀ in deer dung (RCW).
**A.* (*Dimetrota*) *nigripes* (Thomson). Harris Mausoleum (NM3395) 29.8.00, one ♂ in cattle dung (RCW).
**A.* (*Dimetrota*) *puncticollis* Benick. Kilmory Bay east (NG3604) 27.8.00, one ♂, 1 ♀, in horse dung (RCW).
A. (*Dimetrota*) *setigera* (Sharp). Kilmory Bay (NG3603)27.8.00, one ♂, 1 ♀, in horse dung; Kilmory Bay east (NG3604) 27.8.00, 1 ♀ in horse dung; Hallival shearwater greens (NM3997) 28.8.00, one ♀ in deer dung; Coire Dubh (NM3998) 28.8.00, 3 ♀♀ in deer dung on path; Harris Mausoleum (NM3395) 29.8.00, 2 ♂♂, 2 ♀♀, in cattle dung (RCW).
A. (*Chaetida*) *longicornis* (Gravenhorst). Kilmory Bay (NG3603) and Kilmory Bay east (NG3604) 27.8.00, common in horse dung; Hallival shearwater greens (NM3997), one ♀ in deer dung; Harris Mausoleum (NM3395) 29.8.00, 2 ♂♂, 2 ♀♀, in cattle dung (RCW).
A. (*Thinobaena*) *vestita* (Gravenhorst). Kilmory Bay (NG3603) 27.8.00, 3 ♂♂, 3 ♀♀, in seaweed; Dibidil (NM3992) 30.8.00, 3 ♂♂ in rotting seaweed; Bagh na- h-Uamha (NM420971) 1.9.00, 3 ♀♀ in rotten seaweed at top of gully; Port na Caranean (NM424988), 1 ♀ in seaweed (RCW).
**Halobrecta algae* (Hardy). Kilmory Bay (NG3603) 27.8.00, one ♂ in seaweed (RCW).
Drusilla canaliculata (Fabricius). Harris Tree Plot (NM337962) 29.8.00, sieving moss on *Lasius flavus* mound (RCW).
Ocalea picata (Stephens) Guirdil Glen Tree Plot (NG319008), pitfall traps, May-1 September 2000, one ♀ in pitfall; Harris Tree Plot (NM337962), pitfall traps 27 July-31 August, 2 ♂♂, 2 ♀♀ (DB det. RCW); Kinloch (NM401997), from deciduous leaft litter and topsoil, December (K. Sayer det. RCW).
Oxypoda alternans (Gravenhorst). Kilmory Fank Tree Plot (NG362008) 27.8.00, 11 in *Suillus* and other fungi; Kinloch Castle woodlands (NM4099) 28.8.00, 3 in *Sulius* beside path near Turbine House, 31.8.00, 6 in fungi behind the White House, 1.9.00, 4 sieving litter under rotten fungi near Turbine House (RCW).
O. elongatula Aubé. Harris tree Plot (NM337962), pitfall traps, 27 July-31 August, 1 ♀ (DB det. RCW).
O. tirolensis Gredler. Hallival shearwater greens (NM3997) 28.8.00, one ♂ sieving moss; Hallival (NM392967) 27 July-28 August, 4 ♂♂, 1 ♀ (DB det. RCW).
**O. umbrata* (Gyllenhal). Kinloch Castle woodlands (NM4099) 1.9.00, one ♀ sieving litter under rotten fungi near Turbine House (RCW).
Aleochara brevipennis Gravenhorst. Kilmory Cottage, 27.8.00, one ♂ in piece of deer skin on grass (RCW).
A. lanuginosa Gravenhorst. Kilmory Bay (NG3603) 27.8.00, one ♂, 1 ♀, in horse dung and one ♂ in Kilmory Bay east (NG3604) also in horse dung; Harris Mausoleum (NM3395) 29.8.00, one ♂ in cattle dung (RCW).
Emplenota obscurella (Gravenhorst) (= *Aleochara algarum* Fauvel). Kilmory Bay (NG3603), 2 ♂♂, 1 ♀, in seaweed (RCW).
E. grisea Kraatz (= Aleochara grisea (Kraatz)). Kilmory Bay (NB3603) 27.8.00, 2 ♂♂ in seaweed, one ♀ under driftwood on beach (RCW).
E. punctatella Motschulsky. (=*Aleochara obscurella* (Gravenhorst)). Kilmory Bay (NG3603) 37.8.00, common in seaweed, one ♂, 1 ♀, in dead gull on beach; Harris east of boulder beach (NM3495) 29.8.00, 2 ♂♂, 3 ♀♀, in rotting seaweed on boulder beach (RCW).

Pselaphidae

Bryaxix puncticollis (Denny). Harris Tree Plot (NM337962), one ♀ sieving moss on *Lassius flavus* mound, 29.8.00 (RCW).

Geotrupidae

Geotrupes stercorarius (Linnaeus). Kilmory Bay east (NG3604) 27.8.00, in horse dung (RCW).

Scarabaeidae

Aegialia arenaria (Fabricius). Kilmory Bay (NG3603) 27.8.00, 3 under dead gull, one under plastic bottle on beach (RCW).

Aphodius ater (Degeer). Kilmory Cottage (NG3503) 27.8.00, one in deer dung, one in horse dung (RCW).

A. contaminatus (Herbst). Kilmory Bay east (NG3604) 27.8.00, 5 in horse dung; Harris Mausoleum (NM3395) 29.8.00, 8 in cattle dung; Harris east of boulder beach (NM3495) 29.8.00, 3 in deer dung behind storm beach; Dibidil (NM3992) 30.8.00, 3 in deer dung on lawn above beach (RCW). Harris (NM3495) 29.8.00, Barkeval summit (NM3797) 30.8.00 (RK).

A. depressus (Kugelann). Kilmory Bay east (NG3604) 27.8.00, in horse dung; Hallival shearwater greens (NM3997), one in deer dung (RCW); Hallival (NM3996) August 2000, in pitfall traps, 3 (DB det RK); Hallival (NM3996) 28.8.00 (RK).

A. foetens (Fabricius). Kilmory Bay (NG3603) 27.8.00, 2 in horse dung (RCW).

A lapponum Gyllenhal. Harris Mausoleum (NM3395) 29.8.00, one in cattle dung; Dibidil (NM3992) 30.8.00, 3 in deer dung on lawn above beach (RCW); Hallival (NM3996) 28.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

A. rufipes (Linnaeus). Kilmory Bay east (NG3604) 27.8.00, in horse dung; Harris Mausoleum (NM3395) 29.8.00, in cattle dung (RCW). North side of Loch Scresort (NM410999) 30.8.00 (RK).

A. rufus (Moll). Kilmory Bay (NG3603) 27.8.00, 4 in horse dung; Hallival shearwater greens (NM3997) 28.8.00, 4 in deer dung (RCW).

Serica brunnea (Linnaeus). Harris east of boulder beach (NM3495) 29.8.00, one dead in plastic box in stream (RCW); Guirdil (NG319008) May-August, pitfall traps, 1 (DB det. RK).

Dascillidedae

Dascillus cervinus (Linnaeus). Harris east of boulder beach (NM3495) 29.8.00, one dead under stone on grassy lawn behind storm beach; Hallival (NM392967), pitfall traps 27 July-28 August, one and one dead under juniper (DB det. RCW); Harris (NM3495) 29.8.00 (RK).

Scirtidae

Cyphon palustris Thomson. Hallival (NM392967), one ♂ on wing, 28.8.00 (RCW).

C. padi (Linnaeus). Kilmory Dunes (NG3604) 27.8.00; Harris (NM3495) 29.8.00; Loch Gainmhich (NM3798) 30.8.00 (RK).

Byrrhidae

Simplocaria semistriata (Fabricius). Harris Tree Plot (NM337962) 27 July-31 August, pitfall traps, one ♂ (DB det RCW).

**Byrrhus fasciatus* (Forster). Hallival (NM392967) 27 July-28 August, 6 in pitfall traps (DB det. RK).

B. pilula (Linnaeus). Hallival (NM392967) 27 July-28 August, one ♀ in pitfall trap (DB det RCW).

Dryopidae

Dryops luridus (Erichson). Harris east of boulder beach (NM3495) 29.8.00, one ♀, one larva under stones on grassy lawn above beach, one ♂ under driftwood in stream (RCW).

Elateridae

Hypnoidus riparius (Fabricius). Kinloch Castle woodlands (NM4099) 1.9.00, sieving litter under rotten fungi near Turbine House (RCW); Hallival (NM392967) 27 July-28 August, pitfall traps, 20+ (DB det. RCW); Kinloch, behind the White House (NM402992), 21 pitfall traps, 2 July-1 September and 3, 2.8.00; Hallival (NM392967); 27 July-28 August, 11 in pitfall traps; Guirdil (NG319008) May-August, 47 in pitfall traps (DB det. RK); Barkeval summit (NM3797) 30.8.00 (RK).

Zorochros minimus (Boisduval & Lacordaire). Hallival (NM337962), pitfall traps, 27 July-31 August, very common in pitfall traps and 4 under juniper (DB det. RCW); and 47 also in pitfalls (DB det. RK); Hallival (NM3996) 28.8.00; Harris (NM3495) 29.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

Ctenicera cuprea (Fabricius). Hallival (NM337962), pitfall traps, 27 July-28 August, 7 (RCW).

Aplotarsus incanus (Gyllenhal) (= *Selatosomus incanus*). Kinloch Castle woodlands (NM4099), one ♂ sieving litter under rotten fungi near Turbine House (RCW).

Cantharidae

Rhagonycha elongata (Fallén). Kinloch Castle woodlands (NM4099) 1.9.00, ♂ and ♀ sieving litter under rotten fungi near Turbine House (RCW).

Anobiidae

Anobium punctatum (De Geer). Kilmory Cottage (NG3503), 27.8.00, borings in planks beside hut (RCW); Kinloch (NM4099) 30.8.00, in woodwork in Kinloch Castle (RK).

Nitidulidae

Epuraea aestiva (Linnaeus). Kinloch Castle woodlands (NM4099) 27.8.00, one ♂ sweeping road verge (RCW); Kilmory Dunes (NG3604) 27.8.00 (RK).

**E. melanocephala* (Marsham). Kinloch (NM402992), pitfall traps behind the White House, 27 July-1 September, one ♂ (DB det. RCW).

Rhizophagidae

Rhizophagus dispar (Paykull). Kinloch Castle woodlands (NM4099) 31.8.00, one in *Piptoporus betulinus* on dead standing birch, and one under bark of cut pine stump (RCW).

Cryptophagidae

Cryptophagus dentatus group. Females of this group of closely-related species cannot be separated. Kinloch Farm barns (NM4099) 31.8.00, 4 ♀♀ sieving hay (RCW).

C. laticollis Lucas. Kinloch Farm barns (NM4099) 31.8.00, 2 ♂♂, one ♀ sieving hay (RCW).

C. saginatus Sturm. Kinloch Farm barns (NM4099) 31.8.00, 4 ♀♀ sieving hay (RCW).

Micrambe vini (Panzer). Kinloch Castle woodlands (NM4099) 30.8.00, beating gorse (RCW).

Atomaria (*Anchicera*) *apicalis* Erichson. Harris, east of boulder beach (NM3495) 29.8.00, one ♂ in rotting seaweed on boulder beach; Kinloch Farm barns (NM4099) 31.8.00, sieving hay (RCW).

A. lewisi Reitt. Kinloch Farm barns (NM4099) 31.8.00, 5 sieving hay; Kinloch (NM4099) 31.8.00 sieving compost heap (RCW).

**A. nigripennis* (Kugelann). Kinloch Farm barns (NM4099) 31.8.00, one sieving hay (RCW). Previously recorded from Kinloch area by Colin Johnston (1993, Atlas of Atomariinae).

**A. rubella* Heer (= *A. berolinensis* Kraatz). Kinloch Castle grounds (NM4099) 27.8.00, one sweeping roadside verge in front of Castle (RCW).

Coccinellidae

Coccinella undecimpunctata Linnaeus. Kilmory Bay (NG3603) 27.8.00, 2 sweeping behind dunes, specimens with large merged spots (RCW).

Endomychidae

Mycetaea hirta (Marsham). Kinloch Farm barns (NM4099) 31.8.00, sieving hay (RCW).

Lathridiidae

**Cartodere constricta* (Gyllenhal). Kinloch Farm barns (NM4099) 31.8.00, 3 sieving hay (RCW).

Lathridius anthracinus Mannerheim. Kinloch Farm barns (NM4099) 31.8.00, very common sieving hay (RCW).

Corticaria elongata (Gyllenhal). Kinloch Farm barns (NM4099) 31.8.00, one ♂ sieving hay (RCW).

**Dienerella ruficollis* (Marsham). Kinloch Farm barns (NM4099) 31.8.00, one ♂, 6 ♀♀ sieving hay (RCW).

Cisidae

Cis nitidus (Fabricius). Kinloch Castle woodlands (NM4099) 27.8.00, 2, and 31.8.00, 13 in *Piptoporus betulinus* on dead standing birch (RCW).

Mycetophagidae

Typhaea stercorea (Linnaeus). Kinloch Farm barns (NM4099) 31.8.00, 34 sieving hay (RCW).

Anthicidae

**Anthicus floralis* (Linnaeus). Kinloch Farm barns (NM4099) 31.8.00, one ♂, one ♀ dead, sieving hay (RCW).

Chrysomelidae

Chrysolina staphylaea (Linnaeus). Kilmory Bay (NG3603) 27.8.00, on grazed turf behind dunes (RCW); Hallival (NM392967) 1.9.00, one under juniper (DB det. RCW); Hallival (NM3996) 28.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

Phratora (= *Phyllodecta*) *vitellinae* (Linnaeus). Kilmory Dunes (NG3604) 27.8.00 (RK).

Galeruca tanaceti (Linnaeus). Coire nan Grunnd (NM4095) 28.8.00; Loch Fiachanis (NM3594) 29.8.00 (RK).

Lochmaea suturalis (Thomson). Coire Dubh (NM3998) 28.8.00, many sweeping heather; Harris Mausoleum (NM3395) 29.8.00, sweeping heather on slopes above Mausoleum; Dibidil (NM3992) 30.8.00, sweeping heather above beach; Bagh na h-Uamha, 1.9.00, sweeping above beach; Kilmory Cottage (NG3503) 27.8.00, sweeping turf (RCW); Kilmory Dunes (NG3604) 27.8.00; Harris (NM3495) 29.8.00; Loch Fiachanis (NM3594) 29.8.00 (RK).

**Phyllotreta undulata* Kutschera. Kinloch (NM4099) 27.8.00, one sweeping field beside Castle (RCW).

**Longitarsus holsaticus* (Linnaeus). Kinloch Farm barns (NM4099) 31.8.00, one sieving hay (RCW).

L. luridus (Scopoli). Kilmory Cottage (NG3503) 27.8.00, one ♂, one ♀ sweeping turf; Kilmory Bay (NG3603) 27.8.00, 6 sweeping behind dunes; Kinloch (NM4099) 27.8.00, 8 sweeping road verge; Harris Mausoleum (NM3395), 7 sweeping slopes above Mausoleum (RCW).

**L. pratensis* (Panzer). Kilmory Cottage (NG3503) 27.8.00, one ♂, one ♀ sweeping *Plantago*; Harris Mausoleum (NM3395) 29.8.00, one ♂, 4 ♀♀ sweeping slopes above Mausoleum (RCW).

Apionidae

**Apion frumentarium* (Paykull) (= *miniatum* Germar). Guirdil (NG319008), pitfall traps, May-August, one (DB det. RK).

Protapion ononicola Bach. Kinloch (NM4099) 27.8.00, 10 sweeping roadside verge in front of Castle (RCW).

Curculionidae

Otiorhynchus arcticus (Fabricius). Hallival (NM3996) 28.8.00, below summit, 2 under stones (RCW); Hallival (NM392967) 27.7.00-28.8.00, 16 in pitfall traps; 1.9.00, 3 under juniper (DB det. RCW); Kilmory Dunes (NG3604)

27.8.00 (RK); Bealach an Oir (NM3895) 28.8.00 (DP); Hallival (NM3996) 28.8.00; Harris (NM3495) 29.8.00; Loch Fiachanis (NM3594) 29.8.00; Barkeval summit (NM3797) 30.8.00 (RK).

O. atroapterus (De Geer). Kilmory Bay (NG3603) 27.8.00, one drowned in plastic box in dunes; Kilmory Bay east (NG3604) 27.8.00, on dune slope (RCW).

O. ligneus (Olivier). Harris (NM3495) 29.8.00 (RK); Kinloch (NM4099) 29.8.00 (DP).

**O. nodosus* (Müller). Kilmory Fank (NG3603) 30.8.00, one in pitfall trap (DB det. RK).

O. singularis (Linnaeus). Kinloch (NM4099), in Castle courtyard; Kilmory Cottage (NG3503) 27.8.00, under stone; Harris Tree Plot (NM337962) 29.8.00, one in hooded crow's nest in oak; Kinloch Castle woodlands (NM4099), 2 sieving moss (RCW); Guirdil (NG319008) May-August, 4 in pitfall traps; Harris Tree Plot (NM337962), four in pitfall traps (DB det. RCW); Kinloch (NM4099), behind the White House, pitfall traps, 2 July, one, 2 August, one; Kilmory Fank Tree Plot (NG362008) 2 July-11 August 2000, 5 in pitfall traps (DB det. RK).

O. sulcatus (Fabricius). Kinloch (NM4099), sieving compost heap (RCW); Guirdil (NG319008), pitfall traps, May-August 2000; 1.9.00, one in pitfall trap; Kinloch (NM402992), pitfall traps behind the White House; one in pitfall (DB det RCW).

Barypeithes araneiformis (Schrank). Kinloch Castle woodlands (NM4099) 1.9.00, 4 sieving litter under rotten fungi near Turbine House (RCW); Kinloch (NM402992), pitfall traps behind the White House, 27 July-1 September, one in pitfall (DB det. RCW); also July 2000, 20; 2 August 2000, 21 (DB det. RK).

Philopedon plagiatus (Schaller). Samhnan Insis (NG379043) 27.8.00 (RK).

Strophosoma melanogrammus (Forster). Kinloch Castle woodlands, 28.8.00, beating birch foliage (RCW).

Barynotus squamosus Germar. Hallival (NM392967) 27 July-28 August, one in pitfall trap (DB det. RCW).

Sitona lepidus Gyllenhal. Kinloch (NM4099) 27.8.00, sweeping *Lathyrus* in Met Station field; 31.8.00, sieving compost heap (RCW).

S. lineellus (Bonsdorff). Harris Mausoleum (NM3395) 29.8.00, 4 sweeping around Mausoleum (RCW); Harris (NM3495) 29.8.00 (RK).

Hypera nigrirostris (Fabricius). Harris Mausoleum (NM3395) 29.8.00, one teneral, sweeping around Mausoleum (RCW).

Anoplus plantaris (Naezen). Bagh na h-Uamha (NM420971), sweeping birch above gorge to beach (RCW).

Ceutorhynchus contractus (Marsham). Kinloch Farm barns (NM4099) 31.8.00, sieving hay (RCW).

Anthonomus brunnipennis (Curtis). Kinloch (NM4099) 27.8.00, one ♂, one ♀ on *Potentilla erecta*; Bagh na h-Uamha (NM420971) 1.9.00, 2 sweeping *P. erecta* behind boulder beach (RCW).

Rhynchaenus fagi (Linnaeus). Kinloch (NM4099). A few typical mines in *Fagus*, 30.8.00 (KB).

Scolytidae

Hylurgops palliatus (Gyllenhal). Kinloch Castle woodlands (NM4099) 31.8.00, 6 under bark of cut pine stump (RCW).

HYMENOPTERA

Little attention was paid to this order during the 2000 team survey but Keith Bland investigated gall wasps belonging to the Tenthredinidae and Cynipidae confirming two more old Heslop Harrison records *Xestophanes brevitarsis* (Thomson) (Harrison, 1948) and *Andricus ostreus* (Hartig) (Harrison, 1938). David Phillips, in addition to his work on Diptera, investigated the Fomicidae and Apidae and recorded the ant *Formica lemani* Bondroit which is new to the Rum checklist. David Horsfield and Roger and Rosy Key also contributed.

Tenthredinidae

Heterarthrus vagans (Fallèn). South side, Loch Scresort (NM4099-4199), mines with disks on alder leaves, 31.8.00 (KB).

Euura weiffenbachi Ermolenko. Kilmory (NG3503), galls on *Salix repens* stem, 27.8.00; Dibidil track (NM4098) galls on *S. repens*, 28.8.00; Harris (NM3495) 29.8.00 (KB det. A. Liston).

Pontania bella (Zaddach)(= *P. pedunculi* (Hartig)). Kilmory Fank (NG3600), almost smooth galls on *Salix aurita*, emerged 1.5.01 and 12.5.01 (KB det. A. Liston).

P. herbaceae (Cameron) (= *P. crassipes* (Thomson)). Askival (NM3995), galls on *Salix herbacea*, 28.8.00, emerged 20.4.01. (KB); also Hallival (NM3996) (DH).

Pontania sp. Kinloch (NM4099) bean galls in *Salix cinerea* 28.8.00 (KB).

P. collactanea (Foerster). South side, Loch Scresort (NM4098-4199) galls on *Salix repens* 31.8.00 (RK det. KB).

Cynipidae

Xestophanes brevitarsis (Thomson). Harris, galls on stem of *Potentilla erecta* also. Fionchra at 200 m alt August 2003 (GC det. KB); Kinloch (NM4099), stem galls on *Potentilla erecta* 30.8.00 (KB). (This confirms record by J. W. Heslop Harrison 1934 (Harrison, 1948).)

Diplolepis spinosissimae (Giraud). Harris (NM3495) 29.8.00, rounded reddish galls on leaves of *Rosa pimpinellifoli* (KB).

Neuroterus quercusbaccarum Linnaeus. Harris Tree Plot (NM3396) early "hat galls" on underside of oak leaves 29.8.00, also Kilmory North Tree Plot (NG3603) 1.9.00 and Kinloch Glen (NG3900) 31.8.00 (KB).
Andricus curvator Hartig. Harris Tree Plot (NM3396) galls on leaf vein of oak distorting leaves, 29.8.00; also at Kilmory North Tree Plot (NG3603) 1.9.00 and Kinloch Glen (NG3900) 31.8.00 (KB).
A. ostreus (Hartig). Harris Tree Plot (NM3396) small galls on mid rib of oak leaf, 29.8.00; also at Kilmory North Tree Plot (NG3603) 1.9.00 (KB). (This confirms record by J. W. Heslop Harrison (Harrison 1948).)
A. kollari (Hartig). South side, Loch Scresort (NM4099-4199), marble galls on oak, 31.8.00 (KB).
A. fecundator (Hartig). South side, Loch Scresort (NM4099-4199) galls on oak, 31.8.00 (KB).
Periclistus spinosissimae Dettmer. Harris (NM3495) 29.8.00, inquilines in galls of *Diplolepis spinosissimae* - reared 30.5.01 (KB).

Formicidae

Myrmica scabrinodis Nylander. Harris raised beach (NM341954) swarming around parked Landrover, 29.8.00 (DP).
M. ruginodis Nylander. Harris raised beach (NM341954) nest in tussock mound 29.8.00; Kilmory, flushes near Cottage (NG358039) 27.8.00; Allt nam Ba (NG408943) 28.8.00; Coire Dubh (NG3999) 28.8.00 (DP).
Lasius flavus (Fabricius). Harris, track north of Cottage (NM337957-NM338960) nest mounds concentrated towards (NM338960) 29.8.00 (DP); Harris (NM3495) 29.8.00 (RK).
L niger (Linnaeus). Harris, nests under stones on margin of track north of Cottage (NM337957-NM338960) 29.8.00; Kilmory, a late ♀ and nest (NG366044) 27.8.00 (DP).
**Formica lemani* (Bondroit). Allt nam Ba (NG408943), 28.8.00 (DP).

Apidae

Bombus lucorum (Linnaeus). Kilmory Dunes (NG3604) 27.8.00 (DP).
B. pascuorum (Scopoli). Kilmory Dunes (NG3604) 27.8.00 (DP).
B. muscorum (Linnaeus). Cliffs south of Harris (NM3494) 29.8.00 (DP).
Colletes sp. Cliffs south of Harris (NM3494) 29.8.00 (DP).

Braconidae

Meteorus versicolor (Wesmael) (det. M. R. Shaw). Reared from larva of *Macrothylacia rubi* from Kilmory (NG371041) 1.9.00 (CA).

Sphecidae

Mellinus arvensis (Linnaeus). Kilmory (NG3603), one 27.8.00 (KB).

DIPTERA

When the Scottish Entomologists reconvened in late August/early September 2000 David Horsfield, who attended the 1990 survey, worked mainly on the Muscidae. David Phillips concentrated on the Tipulidae adding 3 previously unrecorded species in spite of the fact that this family had been well investigated in the past. He also added a great deal of new localities for previously recorded species. Keith Bland concentrated on gall flies of the Cecidomyiidae confirming 2 more old Heslop Harrison records *Jaapiella loticola* (Rübsaamen) and *Anisostephus betulinum* (Kieffer); also leaf miners and stem borers of the Anthomyzidae and Agromyzidae adding 13 previously unrecorded species. Contributions to the Dipterous fauna also came from Roger and Rosy Key, Colin Welch and Gordon Corbet.

Tipulidae

Nephrotoma scurra (Meigen). Kilmory Dunes (NG3604), ♀, 27.8.00 (DP).
Tipula (=Savtshenkia) marmorata, Meigen. Kilmory Dunes (NG3604), 27.8.00, ♀ (DP).
T. (= *Savtshenkia*) *rufina* Meigen. Kilmory, narrow cleft in rocks on beach (NG366041). 27.8.00 (DP).
**T. montium* Egger. Kilmory, flushes running to beach (NG366044), 27.8.00, ♀ (DP).
T. (=Acutipula) fulvipennis De Geer. Kinloch, woodland on Nature Trail (NM415990),28.8.00 (DP)
T. (= *Platytipula*) *melanoceros* Schummel. Path from Kinloch to Coire Dubh (NG393983 to NG398993), 28.8.00 (DP).
T. paludosa Meigen. Kilmory Fank, flushes on hillside outside fence at the south end of tree plot. Flushes with *Parnassia*, (NG362007), 27.8.00, ♀; Kilmory, flushes near cottage (NG358039) 27.8.00; Kilmory, flushes running to beach (NG366044), ♀, 27.8.00; Kinloch, ascending track to Dibidil (NM4098), 28.8.00; Coire Dubh track (NG393983), 28.8.00, ♀ (DP).
T. (= *acutipula*) *fulvipennis* De Geer. Kinloch, woodland on Nature Trail (NM415990), 28.8.00 (DP).
Limonia (= *Dicranomyia*) autumnalis (Staeger). Harris, pool behind raised beach (NM341957), 29.8.00; Kilmory Fank (NG362007), ♀, flushes on hillside outside south side fence of Tree Plot, abundant *Parnassia*, 27.8.00; Kilmory, flushes near Cottage (NG358039), 27.8.00, ♀, also flushes running down to beach (NG366604), ♀, 27.8.00. East Rum, ascending first part of Dibidil track (NM4098), 28.8.00, ♀. Path from Kinloch to Coire Dubh (NG393983 to NG398993), ♀, 28.8.00 (DP).
L. (= *Dicranomyia*) *mitis* (Meigen). Kilmory, flushes running down to beach (NG366044), 27.8.00 (DP).
**L.* (= *Dicranomyia*) *lutea* agg. Meigen. Kilmory, flushes running down to beach (NG366044), 27.8.00, ♀ (DP).

L. nubeculosa Meigen. Kilmory Dunes (NG3604), 27.8.00 (DP).
**L.* (= *Metalimnobia*) *morio* (Fabricius). Kilmory Fank, flushes with *Parnassia* on hillside outside south side of tree plot (NG362007), 27.8.00 (DP).
Pedicia (= *Tricyphona*) *schummeli* (Edwards). Kilmory Fank (NG362007), flushes with abundant *Parnassia* on hillside outside south side fence of tree plot, ♀, 27.8.00 (DP).
P. (= *Tricyphona*) *immaculata* (Meigen). Kilmory (NG358039), flushes near cottage, ♀, 27.8.00 and flushes running to beach (NG366044), 27.8.00; east Rum, ascending first part of track to Dibidil (NM4098), 28.8.00; Coire Dubh track from Kinloch (NG393983 to NG 398993), 28.8.00 (DP).
Limnophila (= *Phylidorea*) *ferruginea* (Meigen). Kilmory (NG366044), flushes running to beach, 27.8.00 (DP).
L. (= *Phylidorea*) *squalens* (Zetterstedt). East Rum, ascending first part of track to Dibidil (NM4098), 28.8.00 (DP).
L. (= *Euphylidorea*) *meigeni* Verrall. Kilmory Fank (NG362007), flushes with abundant *Parnassia* on hillside outside south side fence of tree plot, 27.8.00; east Rum, ascending first part of track to Dibidil (NM4098), 28.8.00; path to Coire Dubh from Kinloch (NG393983 to NG398993), 28.8.00 (DP).
**L.* (= *Brachylimnophila*) *separata* sensu Stubbs. East Rum (NG393983 to NG398993), path from Kinloch to Coire Dubh (DP).
Pilaria discicollis (Meigen). Harris, pool on raised beach (NM341957) and cliffs south of Harris (NM3494), 29.8.00 (DP).
Gonomyia dentata de Meijere. Harris (NM3494), cliffs to the south, 29.8.00 (DP).
Erioptera trivialis Meigen. Harris, pool on raised beach (NM341957) and cliffs to the south of Harris (NM3494), 29.8.00. Kilmory Fank, flushes with abundant *Parnassia* on hillside outside south end fence of tree plot (NG362007), 27.8.00; Kilmory, flushes running down to beach (NG366044), 27.8.00 (DP).
Molophilus griseus (Meigen). Kinloch, woodland on Nature Trail (NM415990), 28.8.00 (DP).

Ptychopteridae

**Ptychoptera lacustris* (Meigen). Harris (NH3495), ♀, 29.8.00 (DP).

Cecidomyiidae

**Dasineura crataegi* (Winnertz). Harris Tree Plot (NM3396), 29.8.00, galled and condensed shoots on lee of bushes (KB).
**Dasineura pteridicola* (Kieffer). Loch Scresort, South Side Natura Trail (NM4198) 31.8.00, galls on *Pteridium* (KB).
Geocrypta galii (Loew). Harris, steep slopes, Glen Duain burn (NM3396), 29.8.00, rounded stem galls on *Galium verum* (KB).
Iteomyia capreae (Winnertz). Kilmory (NG3603), 27.8.00, leaf gall on *Salix aurita*; Kinloch (NM4099), 30.8.00, galls in leaves of *Salix aurita x cinerea* Kilmory enclosure (NG3602), 1.9.00, leaf galls on *Salix aurita*; (KB); Bagh nah-Uamha (NM4197) 1.9.00, near standing stone, leaf galls on *S. aurita* (RCW).
Jaapiella loticola (Rübsaamen). Kilmory (NG3503 and 3603), 27.8.00, Kinloch (NM4099), 30.8.00 and Harris (NM3396), Glen Duain, 29,8.00, terminal bud galls on *Lotus corniculatus*, all empty, but most probably this species (KB). This confirms an early record by J W Heslop Harrison (Harrison 1948).
**Oligotrophus panteli* Kieffer. Kilmory (NG3503), 27.8.00, bud galls on juniper; (det. confirmed by Philip Entwistle) (KB).
**Rhabdophaga rosaria* (Loew) (= *cinerearum* (Hardy)). Kinloch (NM4099), 30.8.00, condensed shoot galls on *Salix aurita x cinerea* and *S. cinerea*; Kilmory enclosure (NG3602) 1.9.00, rosette galls on *S. aurita* (KB).
Rhopalomyia ptarmicae (Vallot). Harris Tree Plot (NM3396), 29.8.00 and Kinloch (NM4099), 30.8.00, galled flowers of *Achillea ptarmicae* (KB).
Asphondylia thymi Kieffer. Harris (NM3396), steep banks by Glen Duain burn (29.8.00), galled seedheads of *Thymus*, a few (KB).
Anisostephus betulinum (Kieffer). Kinloch (NM4099), 30.8.00, single blister gall on birch (KB). This confirms former record from Kinloch (Harrison, 1948).

Rhagionidae

Rhagio lineola Fabricius. Woodland on Nature Trail, Kinloch (NM415990) 28.8.00 (DP).
R. scolopacea (Linnaeus). Kinloch Glen Nature Trail (NG3900), 3.6.00 (KB).

Tephritidae

Tephritis leontodontis (de Geer). Harris Tree Plot (NM3396) 29.8.00, several (KB).
Tephritis vespertina (Loew). Kinloch Glen (NG3900) 31.8.00, exuvia in heads of *Hypachoeris radicata* (KB).
Trypeta zoe (Meigen). Kinloch (NM4099), 28 & 30.8.00, broad linear mines following veins in *Senecio aquaticus* (KB).
**Sphenella marginata* (Fallèn). Kinloch (NM4099), 27.8.00, two taken in field dominated by *Senecio aquaticus* (RK det. KB); also, 30.8.00, puparia in capitula of *S. aquaticus*, flies emerged 8-11.11.00 (KB).
**Rhagaletis alternata* (Fallèn). Loch Scresort, South Side Nature Trail (NM4198), 31.8.00, tunnels in hips of rose, one fly emerged 24.5.01 (KB).

Anthomyiidae

**Chirosia betuleti* (Ringdahl). Kinloch (NM4099), 30.8.00, curled frond-tips of fern - all empty (KB).

Chirosia histricina (Rondane). South side of Loch Scresort (NM4198) 31.8.00, mines in bracken fronds (KB).

**Delia piliventris* (Pokorny). Askival (NM3895), 28.8.00, larvae boring shoots of *Silene acaulis* single puparia (KB).

**Pegomya rubivora* (Coquillett). Kinloch Glen (NG4000) 31.8.00, single exuvium in old dead stem of *Filipendula ulmaria* (KB).

**Phyoscyami* (Panzer) (= *betae* (Curtis)). Harris (NM3395), 29.8.00, larvae mining leaves of *Silene maritima*, one ♂ found to have emerged and died, 3.12.00 (KB).

Agromyzidae

**Agromyza albitarsis* Meigen. South Side Nature Trail, Loch Scresort (NM4198), 31.8.00, black mine in suckers of aspens (KB).

**Agromyza alnivora* Spencer. Kinloch (NM4099), 30.8.00, many mines in alder; (KB). Kinloch Glen (NM3899) 30.8.00 (DH).

**A. alnibetulae* Hendel. Kinloch (NM4099), 30.8.00, many mines in leaves of birch (KB).

**A. demeijerei* Hendel. Kinloch (NM4099) 27.8.00, vacated mines in leaves of *Laburnum* and 30.8.00, occupied mines (KB).

A. johannae de Meijere. Harris Tree Plot (NM3396) 29.8.00, a few aborted early mines in broom (KB).

A. nana Meigen. Kilmory Fank (NG3600), 27.8.00, single occupied blotch mine in *Trifolium repens*, one imago found to have emerged and died, 3.12.00; Kilmory enclosure (NG3602) 1.9.00, roadside, single blotch mine in *T. repens*; Kinloch (NM4099) 30.8.00, mines in *T. repens* & *T. pratense* (KB).

**A. filipendulae* Spencer. Kinloch (NM4099), 30.8.00, vacated mines in *Filipendula ulmaria* and raspberry (KB).

**A. phragmitidis* Hendel. Kinloch (NM4099), 30.8.00, multi larval mines in leaves of *Phragmites*, two flies emerged, 24.9.00 and 7.11.00 (KB).

**A. potentillae* Kaltenbach. Kinloch (NM4099), 30.8.00, vacated mines in *Filipendula ulmaria* and raspberry (KB).

**Aulagromyza tremulae* (Hering). South Side Nature Trail, Loch Scresort (NM4198), 31.8.00, early mines in *Aspen* (KB).

**Cerodontha iraeos* (Robineau-Desvoidy). Kinloch (NO4099) 30.8.00, mines with puparia in *Iris pseudacorus* (KB).

**Napomyza lateralis* (Fallén). Kinloch (NO4099) 30.8.00, larvae in capitula of *Tripleurospermum*, fly emerged 10.9.00 (KB).

**Phytoliriomyza hilarella/pteridii* (Zetterstedt). South side of Loch Scresort (NM4198) 31.8.00, mines in bracken fronds of one of these two species (KB).

**Phytomyza affinis* Fall. Kilmory Fank (NG3600) 27.8.00, three puparia in old seed heads of *Euphrasia* (KB).

P. aprilina (Grosh.) Kilmory (NG3603), 27.8.00, stellate linear mines in *Lonicera periclymen*, puparia in mines; South Side Nature Trail, Loch Scresort (NM4099 and NM4198), mines in leaves of *Lonicera periclymen*, one fly emerged 10.9.00 (KB); Bagh na h-Uamha (NM4197), 1.9.00, near standing stone, stellate mines in *Lonicera* (RCW).

Phytomyza angelicae Hering Kilmory (NG3603), 27.8.00, blotched mines on *Angelica sylvestris*, 2 imagines emerged 17.9.00; Coire Dubh, near dam (NM3998), 28.8.00, yellowish blotch mines in *Angelica*; Kinloch near Castle (NM4099), mines in *Angelica*; Harris Tree Plot (NM3396), 29.8.00, mines in *Angelica*; Kinloch (NM4099), 30.8.00, yellow blotch mines in *Angelica sylvestris* (KB).

P. angelicastri Hering Kinloch (NM4099) 30.9.00, linear mines in *Angelica sylvestris* (KB).

**P. cecidonomia* Hering Harris (NM3396), 29.8.00, mines in *Centaurea nigra* with vacated puparium in mine (KB).

P. ilicis Curt. Kinloch near Castle (NM4099), 28.8.00 and 30.8.00, mines in holly (KB).

P. obscurella Fallèn. Kinloch (NM4099), 30.8.00, linear vacated mines on *Aegopodium* (KB).

P. plantaginis Goreau. Harris (NM3396), 29.8.00, mines in *Plantago lanceolata* (KB).

P. primulae Goreau. Coire Dubh, near Hydro dam (NM3998), 28.8.00, mines in *Primula vulgaris* (KB).

P. rostrata Hering. Kinloch (NM4099), 30.8.00, puparia in stems of *Rhinanthus* and *Odontites verna*; flies emerged, 8.10.00 (KB).

**P. tenella* Meigen. Kilmory (NG3503), 27.8.00, single pupa in seed head of *Pedicularis sylvestris*; one imago emerged 15.7.02 (KB).

P. varipes Macquart. Harris (NM3396), 29.8.00, single puparium in seedhead of *Rhinanthus*; Kinloch (NM4099), 30.8.00, puparia in seedheads of *Rhinanthus* (KB).

**P. virgaureae* Hering. Hallival (NM3894) (NM3996), 28.8.00, occupied mines in *Solidago* (KB, DH). Around Hydro dam, Coire Dubh (NM3998), 28.8.00, linear mines in *Solidago virgaurea*; Dibidil path (NM4195) 28.8.00, mines in *Solidago* (KB).

Napomyza lateralis (Fallèn). Kinloch (NM4099), 30.8.00, mines in capitula of *Tripleurospermum maritima*. One imago emerged, 30.4.01 (KB).

Syrphidae

Platycheirus clypeatus (Meigen). Harris, pool on raised beach (NM341955) 29.8.00 (DP). Kilmory, flushes near Cottage (NG358039) 27.8.00 (DP).

Eristalis abusivus (Collin). Harris, pool on raised beach (NM341955) 29.8.00 (DP).

Hippoboscidae

Lipoptena cervi (Linnaeus). Kilmory (NG3503) 27.8.00, several adults (KB). Harris, ♂ on GC, wings shed. Loch Scresort, N shore ♀ on GC, one wing in tact, August 2000 (GC). Kilmory Dunes (NG3604) 27.8.00 (RK).

SIPHONAPTERA (FLEAS)

In the course of sieving moss in the Kinloch Castle woods Colin Welch added one previously unrecorded flea.

Ceratophyllidae

**Ceratophyllus frigillae* (Walker). One ♀, sieving moss and leaf litter in Kinloch Castle woodlands, 1.9.00 (RCW).

ACKNOWLEDGEMENTS

The participants would like to thank Scottish Natural Heritage, and especially Denise Reed for all the help with transport and accommodation while on the Island. Thanks are also due to John Walters and Linda Ross at Fraser Darling House, Inverness for their help with the typing and computer storage of all the Rum entomological data; for having to contend with the ever-changing taxonomic tabulation and the eccentricities of entomologists and their variable punctuation.

REFERENCES

Bland, K.P. 2001. *Cosmopterix orichalcea* Stainton (Lep: Cosmopterigidae) A resident species on the Isle of Rum, Scotland. *Entomologist's Record and Journal of Variation* 113, 262-263.

Bland, K.P. 2001. New food-plant for *Leucoptera orobi* Stainton (Lep: Lyonetiidae) from the Isle of Rum, Scotland. *Entomologist's Record and Journal of Variation* **113**, 263.

Bradley, J.D. 1998. *Checklist of Lepidoptera recorded from the British Isles*. 106pp. D. J. & M. J. Bradley.

Hancock, E.G. 1992. Some records of terrestrial invertebrates from Rum National Nature Reserve, 1990. *Glasgow Naturalist* **22**, 169-189.

Harrison, J.W.H.1938. A contribution to our knowledge of the Lepidoptera of the islands of Coll, Canna, Sanday, Rhum, Eigg, Soay and Pabbay (Inner Hebrides) and of Barra, Mingulay and Berneray (Outer Hebrides). *Proceedings of the University of Durham, Philosophical Society* **10,** 10-23.

Harrison, J.W.H. 1939. The gall-making Hymenoptera of some of the Western Islands of Scotland. *Entomologist's Monthly Magazine* **74**, 60-63.

Harrison, J.W.H. 1940a. More records of gall-making Hymenoptera in the Inner and Outer Hebrides. *Entomologist's Monthly Magazine* **75**, 245-246.

Harrison, J.W.H. 1940b. The genus *Zygaena* in the Western Isles of Scotland. *Entomologist's Record and Journal of Variation* **52**,134-137.

Harrison, J.W.H. 1940c. *Somatochlora arctica* Zett. A dragonfly new to the Hebrides on the Isle of Rhum. *Entomologist* **75**, 45.

Harrison, J.W.H.1944. *Nepticula anomalella* on wild rose in the Isle of Rhum. *Entomologist's Record and Journal of Variation* **56**, 108.

Harrison, J.W.H. 1945. Coccinella 11-punctata L. var. *boreolitoralis* Donis. (Col. Coccinellidae) in the Inner and Outer Hebrides. *Entomologist's Monthly Magazine* **81**, 11.

Harrison, J.W.H. 1946. The detection of larvae and pupae of *Coccinella 11-punctata* L. var. *borealitoralis* Donis. (Col. Coccinellidae) on the Isle of Rhum. *Entomologist's Monthly Magazine* **82**, 118.

Harrison, J.W.H.1948. Zoocecidia in the Scottish Western Isles. *Entomologist's Monthly Magazine* **84,** 113-116.

Harrison, J.W.H. 1950. *Meloe proscarabaeus* L. in the Isle of Rhum. *Entomologist* **83,** 70.

Harrison, J.W.H. 1955. Lepidoptera of the Lesser Isles of Skye. *Entomologist's Record and Journal of Variation* **67**, 141-147; 169-177.

Heath, J. and Maitland Emmett, A.(eds.) 1979. *The Moths and Butterflies of Great Britain and Ireland. Volume 9, Sphingidae to Noctuidae: Noctuinae and Hadeninae.* Harley Books 288pp.

Horsfield, D. 2002. Some records of *Rhacognathus punctatus* (L.) Hemiptera (Pentatomidae). *Entomologist's Monthly Magazine* **138**, 88.

Kloet, G.S. and Hincks, W.D. 1964-79. *A check list of British Insects (2nd edn)*. London, Royal Entomological Society.

Luff, M.L. 1998. Provisional Atlas of the Ground Beetles (Coleoptera, Carabidae) of Great Britain. *Biological Record Centre, Institute of Terrestrial Ecology, Monks Wood* p125 Map 236

Pelham -Clinton, E.C. 1986. *Cosmopterix orichalcea* Stainton in the Isle of Rhum. *Entomologist's Record and Journal of Variation* **98,** 143.

South, R. 1961. *The Moths of the British Isles: Volume 1.* London, Frederick Warne & Co. Ltd., 427pp.

Steel, W.O. and Woodroffe, G.E. 1969. The Entomology of the Isle of Rhum National Nature Reserve. *Transactions of the Society for British Entomology* **18**, 91-167.

Welch, R.C. 2001. *Gyrophaena poweri* Crotch (Staphylinidae) new to Scotland from Rum National Nature Reserve. *The Coleopterist* **10**, 93.

Welch, R.C. 2003. Early records of *Gyrophaena poweri* Crotch (Staphylinidae) from Scotland and Wales. *The Coleopterist* **12**, 31-32.
Whiteley, D. 1994. A Survey of Diptera on the Isle of Rum, 1990. *Dipterists Digest* **14**, 2-27.
Wormell, P. 1982. The Entomology of the Isle of Rhum National Nature Reserve. *Biological Journal of the Linnaean Society* **18**, 291-401.
Wormell, P. In preparation. Insects of the Isle of Rum.

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 155-158.

SHORT NOTES

FALSE LUPIN (*THERMOPSIS MONTANA*) IN LANARKSHIRE

P. Macpherson & B. Simpson
15 Lubnaig Road, Glasgow, G43 2RY
73 Lavender Drive, East Kilbride, G75 9JH

In the spring of 2004 BS noted unusual foliage growing in the valley of a little burn fairly close to the Lanarkshire/Ayrshire boundary. We went to the site on 24th June when the plant was in flower and subsequently were able to identify it as False Lupin, a member of the Pea Family.

It was situated between an abandoned sheep fank and the Powbrone Burn approximately 1¾ km from the B743 and SE of Glengavel Reservoir, Lanarkshire (VC 77). The grid reference is 26/691345.

At a return visit in 2005 the colony was noted to be an irregular patch of 7 x 3m, 9m from the fank and 30m from the burn. Plant associates were Bracken (*Pteridium aquilinum*, Soft-rush (*Juncus effusus*), Heather (*Calluna vulgaris*) and Rosebay Willowherb (*Chamerion angustifolium*).

The plant is a native of Western N America. It is rarely grown in gardens. With regard to the British distribution "in the wild", it was established for about 25 years in gravel pits at Oundle, Northants (now gone) and on the riverside at Canonbie, Dumfriesshire (Clement & Foster (1994). It was reported to have been present since about 1978 in a derelict garden at Houbie, Fetlar, Shetland (Scott & Palmer 1987).

One can only speculate as to how this rarity came to be established in a remote Lanarkshire glen. Possibilities include accidental introduction with animal feed and bird-sown from Dumfriesshire. There has also been afforestation in the area.

REFERENCES

Clement, EJ & Foster, MC (1994). *Alien Plants of the British Isles*, Botanical Society of the British Isles, London.

Scott, W & Palmer, R (1987). *The Flowering Plants and Ferns of the Shetland Islands*, Shetland Times Ltd. Lerwick.

ALEXANDER PATIENCE (1865-1954): ADDENDA

P. G. Moore
University Marine Biological Station Millport,
Isle of Cumbrae KA28 0EG

Researching further around the topic of the history of the Marine Station at Millport has brought to light a couple of items relating to Alexander Patience that were overlooked by Moore & Hancock (2004).

In the Annual Report of the Marine Biological Association of the West of Scotland for 1902 it is recorded that Thomas Scott had named a parasitic isopod *Pleurocrypta patiencei* Scott, 1902 after Mr Alex. Patience; its discoverer (Marine Biological Association of the West of Scotland, 1903, p.7). Sadly, this name has been synonymised with the other bopyrid species discovered by Patience and described by Scott as *P. cluthae* Scott, 1902, so Alexander Patience remains honoured in the nomenclature of British crustaceans only via the woodlouse *Miktoniscus patiencei* Vandel, 1946 (as reported by Moore & Hancock, 2004).

This next snippet is noted in the hope that it might stimulate further interest in the later years of this little-known carcinologist. He was reported (still from an address of 140 London Street, Glasgow, i.e. that of his employers Wm Metcalfe & Sons), among the List of Fellows of the Royal Physical Society of Edinburgh for 1 October 1923 (as having been elected 1910). This is interesting because, as Moore & Hancock (2004) pointed out, his scientific publications come to an abrupt halt in 1911.

REFERENCES

Marine Biological Association of the West of Scotland, 1903. Annual Report for 1902. Glasgow: N. Adshead & Son, 48pp.

Moore, P. G. & Hancock, E. G., 2004. Alexander Patience (1865-1954): Glasgow's little-known Edwardian carcinologist. *Glasgow Naturalist*, **24**: 119-129.

NEW RECORDS OF THE AMPHIPOD *MICROJASSA CUMBRENSIS* (FAMILY ISCHRYOCERIDAE) IN THE FORTH SEA AREA.

Myles O'Reilly
Scottish Environment Protection Agency
Redwood Crescent
East Kilbride, Glasgow G75 5PP
myles.oreilly@sepa.org.uk

The amphipods from the Forth Sea Area were recently reviewed by O'Reilly *et al.* (2001). They identified a number of species new to the area and among these was a single female specimen of *Microjassa cumbrensis* from off St.Abbs in June 1989 which represented the first record of this species from the east coast of Britain. Further records of *M. cumbrensis* have recently come to light in the course of sampling by SEPA on 9th Feb 2004, at Kingston Hudds (56 °07.441'N., 02°55.923'W., depth 40m), 7 km south of East Largo Bay in the Firth of Forth.

The new specimens comprise 4 females, 2 of which are ovigerous, and all are around 1.5mm long. *M. cumbrensis* is a difficult species to recognise due in part to its small size. It does not possess the distinct toothed outer ramus of uropod 1, characteristic of many ischyrocerids (see Lincoln, 1979) and the

diagnostic enlarged second gnathopods are present only in the males which are much less commonly encountered than females. The inexperienced observer presented with female *M. cumbrensis* is easily misled by the acute eye lobe which suggests it may be a juvenile *Gammaropsis cornuta.* However careful examination of the carpus of the gnathopods shows these to be oval with smooth palms and lacking the distinct profile of *G. cornuta* or the other british *Gammaropsis* species. The discovery of new material of *M. cumbrensis* at a new site in the Forth Sea Area suggests that is probably fairly widely distributed and in many cases may be overlooked or misidentified.

REFERENCES

Lincoln, R.J. (1979). British Marine Amphipoda: Gammaridea. British Museum (Natural History), 658 pp.

O'Reilly, M., Hamilton, E. & Heaney, L. (2001). New records of Amphipods and Leptostracans from the Forth Sea Area, with notes on their copepod parasites (Siphonostomatoida: Nicothoidae). *Glasgow Naturalist* 23,(6), 35-42.

THE JAPANESE MACHO SKELETON SHRIMP (*CAPRELLA MUTICA*) IN THE CLYDE ESTUARY

Myles O'Reilly

Scottish Environment Protection Agency
Redwood Crescent
East Kilbride, Glasgow G74 5PP
myles.oreilly@sepa.org.uk

Skeleton Shrimps are amphipod crustaceans belonging to the families Caprellidae and Phtisicidae. There are thirteen species native to British waters. The japanese "Macho" Skeleton Shrimp is a recent arrival in Europe. It was first discovered in Dutch waters by Platvoet *et al.* in 1995. Although regarded as probably an accidental alien import, its true identity was not realised at the time and they described it as a new species "*Caprella macho*", alluding to the hairy appearance of the large robust males.

The same shrimp first came to light in UK waters in July 2000 when specimens from a fish farm near Oban were sent to the Dunstaffnage Marine Laboratory for identification. Its true identity was then recognised as *Caprella mutica*, a species originally described from the Sea of Japan in 1935. Scientists began an investigation to determine its distribution in Scotland (Willis *et al.* 2003, 2004). *C.mutica* appeared to like hanging around on mooring ropes at fish farms. so to help locate new records a web page was set up within the Scottish Association of Marine Science website (www.sams.ac.uk) to alert those in the fish farm industry as well as the sailing fraternity.

It soon became apparent that *C.mutica* was already widespread on the west coast of Scotland in Loch Linnhe, Loch Creran, Loch Sunart, the Sound of Mull and the Western Isles (Cook *et al.,* 2003). It has also turned up in other parts of the UK as well as in Ireland, Germany and Norway (Tierney *et al.* 2004, Buschbaum & Gutow, 2005, Ashton *et al.*, 2006). It was not long before the shrimp "invasion" hit the press headlines (Scotland on Sunday, Sunday Times, Oban Times).

Prompted by this publicity, caprellid shrimps held in the SEPA marine lab reference collection at East Kilbride were re-examined in 2003 and some specimens, initially identified as *C. tuberculata,* turned out to be *C.mutica*. These had been collected in August 1999 at a buoy moored by SEPA at the Roseneath Patch, 1.3km north of Whiteforeland Point, Gourock. Although hundreds of shrimps had been observed on the mooring rope, only 6 had been retained – 4 adult males (about 2cm long), and 2 adult females (about 1cm long). This re-discovery indicated that *C.mutica* had already arrived in the Clyde Estuary before it came to light further north near Oban. Further sampling in September and October 2004 at another SEPA bouy moored at Dunoon Bank (1km east of Dunoon Pier) also revealed the presence of hundreds of *C.mutica*. Numerous specimens were collected and forwarded to the Dunstaffnage Lab to assist with genetic studies. In April 2006 material of the alien ascidian, *Styela clava,* collected from Ardrossan marina also had some *C.mutica* attached indicating the species is now well established throughout the Clyde Sea area.

It is not surprising that the occurrence of *C.mutica* has been overlooked until recently. The only comprehensive identification key for caprellids in UK waters, Harrison (1944), has not been updated since the last world war. In Harrison's key *C. mutica* keys out as *C.tuberculata.* Adult *C.mutica* are generally much larger than *C. tuberculata* and segments 1 and 2 of the males are conspicuously hairy. Dorsal tubercles are usually absent on segments 1 and 2 of *C.mutica*, though in some females small tubercles may be present. The male second gnathopod possesses a relatively straight palmer margin with 2 forward pointing teeth, the second tooth followed by an oblique notch and a smaller third tooth distally. The female second gnathopod is similar in structure but the marginal teeth and notches are very much smaller.

REFERENCES

Ashton, G., Willis, K., Cook, E. & M. Burrows (2006). Distribution of the introduced amphipod *Caprella mutica* Schurin on the west coast of Scotland and a review of its global distribution. *Hydrobiologia* (in press).

Buschbaum, C. and Gutow, L. (2005). Mass occurrence of an introduced crustacean (*Caprella cf.mutica*) in the south-eastern North Sea. *Helgoland Marine Research* 59(3), 252-253.

Cook, E., Willis, K., and Lozano, M. (2003). Alien Invasion. A new non-native invasive species on the west coast of Scotland. *SAMS Newsletter* 28:12
Harrison, H.J. (1944). Caprellidea (Amphipoda, Crustacea). *Synopses of the British Fauna*. No. 2. pp. 1-27. The Linnean Society of London.
Oban Times (15 July 2004). Alien species comes under the microscope at Dunstaffnage.
Platvoet,D., De Bruyne, R.H., and Gmelig Meyling, A.W. (1995). Description of a new Caprella- species from the Netherlands: *Caprella macho* nov.spec. (Crustacean, Amphipoda, Caprellidea). *Bulletin Zoologisch Museum*, 15(1), 1-4.
Scotland on Sunday (7 September 2003). Shrimp invasion poses threat to native shellfish.
Sunday Times (11 april 2004). Alien invasion is wiping out native sea life.
Tierney,T.D., Kane, F., Naughton, O., Kennedy, S.O., Donohoe,P., Copley, L., Jackson, D. (2004). On the occurrence of the caprellid amphipod, *Caprella mutica* Schurin 1935, in Ireland. *Irish Naturalists Journal*. 27(11), 437-439.
Willis, K.J., Cook, E.J., Lozano-Fernandez, M. and Takeuchi, I. (2003). Aquaculture related introductions of the caprellid amphipod *Caprella mutica*. *6th international conference on the biology and control of sealice* (Poster presentation & Abstract). St Andrews, Canada, 1-4 July 2003.
Willis, K.J., Cook, E.J., Lozano-Fernandez, M. and Takeuchi, I. (2004). First record of the caprellid amphipod, *Caprella mutica*, for the UK. *Journal of the Marine Biological Association of the UK*. 84:1027-1028.

A LESSER WEEVER FISH *ECHIICHTHYS VIPERA* IN THE CLYDE ESTUARY

Myles O'Reilly
Scottish Environment Protection Agency
Redwood Crescent
East Kilbride, Glasgow G74 5PP
myles.oreilly@sepa.org.uk

The Lesser Weever (*Echiichthys vipera*) with its venomous dorsal spines is well known as a hazard to bathers and surfers in southern Britain. It is less common further north but occurs in coastal areas along the north coast of Wales, the Liverpool Bay area and up into the Solway Firth (Parker-Humphreys, 2004). They appear to like sandy estuaries and are very common in the Ribble Estuary in Lancashire (Steve Coates, Environment Agency, *pers. comm.*). They feed on a variety of small crustaceans (Vasconcelos *et al.*2004).

The Scottish Environment Protection Agency SEPA (and its predecessor the Clyde River Purification Board) have undertaken assessment of the fish populations in the Clyde Estuary for over 20 years (see Henderson & Hamilton, 1986). During routine beam trawling on 25th May 2004 a Lesser Weever was caught between Crannog and Milton, just west of the Erskine Bridge. The juvenile fish, about 6cm long, was transported alive to the SEPA lab at East Kilbride for closer examination in an aquarium, before being returned to the estuary the following day. It possessed the characteristic oblique mouth, top set eyes and the prominent black first dorsal fin, as well as the typical yellowish tail fin and brown-mottled flanks with a light violet sheen (Dipper, 1987).

Lesser Weevers were described as "very rare" in the Clyde Sea Area by Bagenal, (1965) although Haliday (1969) recorded juveniles around 1.5-2cm long netted in Kames Bay, Millport. Since then they have periodically turned up in Kames Bay and there have been occasional stinging incidents there and on the Ayrshire coast (Jim Atkinson, University Marine Biological Station Millport, *pers. comm.*). It seems likely that moderate numbers are present at all times but the coldness of Scottish waters means few bathers are likely to come in contact with the fish. As the fish prefer shallow sublittoral waters the vulnerable time is paddling at low water. One member of SEPA's staff remembers being stung by a weever fish, as a boy in 1971 at Glasnacardoch Beach (near Mallaig). He subsequently captured and killed the fish. This was before he became more "environmentally aware"! (Pat Duffy, SEPA, *pers. comm.*).

The occurrence of a juvenile Lesser Weever in the Clyde Estuary does appear to be unusual and suggests that a population of adults may be present nearby. However, monitoring of the estuarine fish communities between Dumbarton and Bowling (and further down the estuary at Pillar Bank) has been carried out four times a year since 1979 and no Lesser Weevers have ever been recorded. The nearest record of another Lesser Weever appears to be a specimen held by Glasgow Museums trawled between Dunoon and Innellan in 1976 (Richard Sutcliffe, Glasgow Museums, *pers. comm.*). It is possible that distributions of some estuarine fish species may be shifting in response to environmental changes - whether these be localised water quality improvements, sedimentary changes or perhaps Global warming (Smith, 2002, Hiscock *et al.*, 2004) - but it is too early to say whether the appearance of the Lesser Weever in the estuary is indicative of any trend.

The Scottish Association for Marine Science (SAMS) has carried out annual fish surveys on a number of shores in western Scotland between 2002 and 2005 (Mike Burrows, *pers. comm.* 2005). Lesser Weevers were caught in NW Scotland at Mellon Charles, Firemore, and Ganavan, near Oban at Tralee and Ganavan, and in Lochs Sween and Coalisport, and at Tayinloan on the Kintyre peninsula. In the Firth of Clyde area they were caught on the Kintyre peninsula at Skipness and Carradale and on the Ayrshire coast at Ayr and Girvan. The numbers captured were usually no more than 2-3 per survey though at Firemore and Gairloch up to 13 and 18 respectively were recovered. Overall, between 20 and 30 were

captured per annum with 37 landed in 2005. However, there is no evidence of any increasing trend and press reports (Brown, 2005) that the Lesser Weevers were undergoing a population "explosion" are quite misleading.

REFERENCES

Bagenal, T.B. (1965). The Fauna of the Clyde Sea Area. Fishes. Scottish Marine Biological Association, Millport. 38 pp.

Brown, A. (2005). Paddlers in peril as poisonous weever fish hit the beach. *The Scotsman*, 6 August 2005.

Dipper, F. (1987). British Sea Fishes. Underwater World Publications Ltd., London. 194pp.

Halliday, R.G. (1969). Rare fishes from the Clyde Sea Area. *Journal of Natural History* 9, 309-320.

Henderson, A.R. & Hamilton, J.D. (1986). The status of fish populations in the Clyde Estuary. *Proceedings of the Royal Society of Edinburgh* 90B, 157-170.

Hiscock, K., Southward, A., Titley, I., & Hawkins, S. (2004). Effects of changing temperature on benthic marine life in Britain and Ireland. *Aquatic Conservation: Marine And Freshwater Ecosystems* 14, 333-362.

Parker-Humphreys, M. (2004). Distribution and relative abundance of demersal fishes from beam trawl surveys in the Irish Sea (ICES Division VIIa) 1993-2001. *Science Series Technical Report* No.120, CEFAS Lowestoft, 68 pp.

Smith, P. (2002). Unusual Summer Visitors to the Clyde Sea Area. *University Marine Biological Station Millport, 32nd Annual Report 2001-2002*, pp.4-5.

Vasconcelos, R., Prista, N., Cabral, H., Costa, M.J. (2004). Feeding ecology of the Lesser Weever, *Echiichthys vipera* (Cuvier, 1829), on the western coast of Portugal. *Journal of Applied Ichthyology*, 20 (3), 211-216.

Glasgow Naturalist 2004. Volume 24. Part 4. Pages 159-163.

BOOK REVIEWS

Compiled by Bob Gray

THE BOTANIST IN SKYE AND ADJACENT ISLANDS

C.W. Murray and H.D.B. Birks
Probost and Bergen, 2005, 134pp, softback, 4 colour plates, maps and tables.
ISBN 0-9548971-0-2. £10.
Available from H.J.Birks, Department of Biology, University of Bergen, N-5007, Bergen, Norway.

This 3rd edition of a well produced and readable little book is an important companion for any visitor to this area who loves plants. The opening sections, following the introduction, describe the geology and climate and the varied plant communities which they have produced and lead into the check list. This, arranged in the order and nomenclature of C.H. Stace (1997), gives also former latin names, common and Gaelic names, the last a welcome addition. Also given are the 10km grid squares in Skye and the names of smaller islands where each plant has been found, and its geographical relationships according to Preston and Hill (1997). Appendices detail old records not confirmed recently, lists of planted trees and shrubs and a long list of botanists who have worked in the area starting with Martin Martin. The index of both latin and common names, in two fonts for greater clarity, is a useful conclusion. An addendum is supplied loose, giving information added after publication (best to stick this in to avoid loss!)

Ruth H. Dobson

MOSSES & LIVERWORTS (THE NEW NATURALIST SERIES NO. 97)

Ron Porley and Nick Hodgetts
Collins, London, 2005, 495 pp., colour plates and black & white photographs, diagrams, line drawings and maps. ISBN 0 00 2202123 (hardback), £40. ISBN 0 00 7174004 (paperback), £25.

It is remarkable that mosses and liverworts, and hornworts (together known as bryophytes) have had to wait until now to get their own volume in the superb New Naturalist Series. Given that there are 1052 different kinds in the British Isles, representing 60 per cent of Europe's bryoflora, the book is finally recognition of how important these diminutive green plants really are. With 978 of these recorded from Scotland we should be especially proud and appreciative of our bryological inheritance north of the border!

The book has been an epic undertaking and has pulled together a vast amount of up-to-date information. The opening chapter provides a succinct, background introduction to the three groups of bryophytes, morphology, physiology and reproduction; these sections are necessarily abridged and greater detail can be found in bryological textbooks. Conservation gets a deliberate mention in Chapter 1, rather than the usual finale, along with a discussion of their ecological and cultural importance. The following chapters look at dispersal and distribution, a fascinating topic given the surprising worldwide distribution of some species found here. The importance of the western (Atlantic) distribution pattern is stressed with caution over the potential disastrous impact if predicted climate change models are realised.

The real strength and detail, however, is provided by the remaining chapters, which explore a variety of habitats and examine the characteristic species that can be found in such special places. These chapters start with man-made habitats, with a more southern bias, followed by more 'natural' places such as woodlands, rock outcrops, heaths and water environments. Of special interest to Scotland are the chapters on 'Shagnum and Peatlands' and 'Small Plants in Big Landscapes'.

The book is superbly illustrated throughout, with many colourful close-up shots, showing the characteristic form and colour of a number of species. A good feature is the series of historical, biographical text box accounts of famous bryologists, interspersed throughout relevant chapters. The book uses scientific names throughout, whch may deter some readers, but the authors think this is more apt rather tan many of the recent contrived 'common' or English names.

The two authors must be congratulated on the time and energy they expended on this book. They are both very knowledgeable, experienced bryologists whose enthusiasm and passion frequently shows, helping to enliven the information-packed text. It is hoped that their efforts will be appreciated by a wide readership and that the book will stimulate greater interest in these fascinating plants. A 'must have' for anyone interested in bryophytes!

Keith Watson

A HISTORY OF THE NATIVE WOODLANDS OF SCOTLAND, 1500-1920

T.C.SMout, Alan R. MacDonald & Fiona Watson
Edinburgh University Press, 2005, 434 pp., 16 b&w maps, 38 b&w figures, 16 colour plates and 22 tables. ISBN 0 7486 1241 6 (hardback), £65

Although the title of this substantial volume suggests that it discusses only the period between 1500 and 1920, the year after the founding of the Forestry Commission, in fact a fair amount of the text is devoted to the years before and after this period. Chapter 2 takes us back to the re-colonisation of the land by different species of native tree as the ice retreated about 11,300 years BP (before the present).

It then chronicles the decline of native woods from their maximum land cover of more than 50% around 5000 BP and pts paid to the idea of an ancient Caledonian forest. Chapter 9 deals, most interestingly, with developments during the course of the 20th century, after 1920, shedding insight into how ecologists, as well as foresters, have established the right to manage woodland.

The introductory chapter defines what is meant by native woods and distinguishes between semi-natural woodland and plantations on ancient woodland sites (PAWS). (1% of each according to a 1980's inventory). The question the whole book endeavours to answer is whether Scottish woods were managed in a sustainable way. It is therefore more about management than ecology.

The complete history of native Scottish woodlands will never be fully known but, as time progresses, more research uncovers further details. Some of this research provides information that contradicts previously held views and this book presents these controversies in a clear and concise way with frequent references to author, writers and critics who are expert in their fields. In particular a balance is struck in analysing the relative influence, over the centuries, of man against climate. An aspect that the book does not address, however, was the adverse effect on sustainable land management by the expropriation of the land owned by monasteries in the latter half of the 16th century.

Hence chapter 3 investigates the change in physical size of the woods between 1500 and 1920 particularly with reference to the maps of Timothy Pont and other cartographers. In general terms the effect of population increase and decrease is compared against the effect of climate change, especially the little ice age of the 16th and 17th centuries.

Chapters 4, 5, 6 and 7 study woodland produce, woodlands as pasture and shelter, trading and exploitation of woods before 1800 and woodland management before 1770. The thrust of these chapters is that oak woodland did not only produce timber for construction and charcoal but also provided pasture for deer and for grazing cattle. In the 16th century grazing was kept in check by wolves. Between 1600 and 1900 the climate became less favourable for tree growth, wolf extermination led to increased grazing pressure and population growth also increased pressure on the woods. Hence upland pasture became vestigial. Although the quality of Scottish pinewood timber could not compete with that of the Baltic, the pressure of the Napoleonic Wars at the turn of the 19th century increased the viability of growing Scottish timber. Finally, in the 16th century a start was made on enclosure, especially in lowland oak forest. Gradually a shift occurred away from pasture towards the use of wood for timber and tanbark production using a coppice with standards system. Pinewoods were less well documented. Enclosure was not needed for regeneration as the seeds are windborne and the seedlings light demanding.

In chapters 8 and 9 the effect of non-locals on firstly the pinewoods and secondly the oakwoods is studied in some detail. Between 1600 and 1850 increased external demand determined how woods were used. Only on the west coast, where the moist conditions were inimical to pine regeneration and because of ease of access by boat, was there no strategy for sustainable use. Elsewhere Scots pine still flourishes where exploitation was considerable. Broadleaved woods are more widely distributed than pinewoods and were exploited mainly for the production of charcoal for iron smelting and bark for tanning leather. Over the centuries it was the high price of these products caused by external demand that led to good, sustainable forestry practice. Falling prices led to increased grazing and woodland neglect.

Changes in demand for woodland products, increased numbers of deer and grouse moor and planting of non-native species led to huge changes in the 19th and early 20th centuries.

Four chapters then provide a detailed analysis of woodland history in Rothiemurchus, Strathcarron, Glenorchy and Skye.

Today 17% of the Scottish land surface is afforested of which a mere 1% is semi-natural. Coppice regimes reduced biodiversity by removing weed species but the ecosystem remained essentially healthy if somewhat simplified. Semi-natural pinewoods suffered some extinctions of birds and mammals under clear felling regimes but re-introductions flourish. Some invertebrates and flora were dramatically reduced by clear felling. Of course the huge amount of planting of non-native species both for timber and as ground cover for game has increased biodiversity but has led to a loss of authenticity.This book is not for the faint-hearted and at £65 is aimed mainly at the serious student of Scottish woodland history. The high quality and huge quantity of the research that has gone into the writing of this book reflects the considerable ability of its three distinguished authors.

Bob Gray

KIRK ON THE CRAIG

T Norman Tait

Friends of the McKechnie Institute, Girvan, 2005, 80 pages, softback.

ISBN 0-9544219-3-0, £10

This book is a compilation of photographs, with captions, of the photography of Charles Kirk, a pioneer in natural history photography, on Ailsa Craig between 1896 and 1922.

Nearly all the photos were taken by Charles Kirk. The author has made a montage of two of Charles Kirk's lantern slides for the front cover, and he has also

coloured one of Charles Kirk's pictures using a computer.

The book starts with two maps illustrating the situation and geography of Ailsa Craig, followed by a view and brief description of Ailsa Craig itself.

In her foreword, the Marquess of Ailsa points out that the Craig, a place of mystery and intrigue, has been in her family history for many centuries. Its history includes episodes of smuggling, granite quarrying, and Victorian tourism. She brings us right up-to-date by crediting Bernie Zonfrillo's rat eradication program with the return of the once-numerous puffins to breed in recent years, and the Craig's new status as an RSPB nature reserve.

Norman Tait then recounts how, on discovering an archive of Charles Kirk's slides in Kelvingrove Museum, he set about restoring them, scanning them into his computer, and researching into the history of the man and his work.

Charles Kirk was a taxidermist, photographer and naturalist, who lived from 1872 to 1922. Spending his early years in his birthplace of Edinburgh, he then went to London and became a taxidermist. Working first in Perth then in Glasgow, where he set up his business as a taxidermist in 1896, he was commissioned to construct an exhibit for the Glasgow International Exhibition in Kelvingrove in 1901.

Seabirds became a favourite photographic subject, and seabirds nesting on Ailsa Craig was the theme of this work. Later, his enterprises included illustrating four early bird books published in Glasgow. Most of his known photography is included in this book.

There are many pictures illustrating the life and times of the people on Ailsa Craig, including granite quarry workers and curling stones being made in Mauchline, fishing boats, the SS Ailsa and tourism, lighthouse keepers including the Thomson Family, Ailsa Castle and the Garry Loch, and the Girvan Family who held the tenancy of Ailsa Craig for about a hundred years.

There is an impressive photo of Charles Kirk focussing a half-plate stereo camera with two lenses on a tripod, while balanced on a precipitous slope on the side of Ailsa Craig around 1900. Two of his stereopair bird photographs really jump out at you in three dimensions. In one of these, a gannet stands out impressively from the background which recedes into the distance.

There are photographs of gannets, guillemots, kittiwakes, puffins and coastal features. There is an extract from an article written by James Thomson about his childhood on Ailsa Craig.

The book finishes with a modern photograph of puffins and a postscript, both by Dr Bernie Zonfrillo, in which he salutes that author for his restoration of Charles Kirk's photographs.

David Palmar

FOSSIL INVERTEBRATES
Paul D. Tayloor & David N. Lewis
Natural History Museum, London, 2005, 200 pages, softback, colour photographs. ISBN 0 565 094832, £25.

As the authors explain in the preface this book is an introduction to the more common invertebrate fossils from around the world together with a few others of interest. Their relationship to living species is given due emphasis. The example described and illustrated are of selected genera. Readers must look elsewhere for minute descriptions and identifications at species level.

Following an introduction, the authors have chapters devoted to the colonial animals and their remains, shells and their providers, worms and tubes, arthropods, and finally, echinoderms. As far as actual numbers go, these are limited in a 200-page book, so that no more than about a dozen genera are given with each descriptive section of text. Each genus is illustrated with a photographic example. The captions give the dimensions of a specimen, which may be enlarged in the photograph to the width of a column in what is a quart-sized book. Every photograph is given a descriptive paragraph. About half the book is taken up with these illustrations. There is also a colour section which includes over a dozen photographs of living animals.

The reviewer was most impressed by the incorporation of the latest scientific advances in geology in a text that is well edited. The index is also well constructed.

Julian Jocelyn

TREES: A FIELD GUIDE TO THE TREES OF BRITAIN AND NORTHERN EUROPE
John White, Jill White and S. Max Walters
Oxford University Press, 2005, 431 pages, hardback, colour photographs. ISBN 0-19-851574-X, £25

This book possesses several features not commonly found in other tree identification guides – a simple but effective key, distribution maps and photographs opposite the text referred to rather than elsewhere in the book.

Most of the chapters are sequenced according to leaf shape and whether these leaves are opposite or alternate. An additional aid is that each chapter is colour coded on the "thumb" side of the pages. The tree species are not arranged in botanical order. Since the professed aim of the book is ease of identification of an unknown species this system certainly narrows down the available options quite dramatically. However, it does have the disadvantage that members of a diverse group, such as the maples, occur in completely different parts of the book. Winter twig identification is brushed aside with the practical

comment that some dead leaves will be found in the area of the specimen.

The distribution maps are reminiscent of some field guides to bird species. Maps showing the natural range and written details of the cultivated distribution of each tree are very clear and interesting, helping to make the book most enjoyable and readable. They have little to do with identification, however.

The photographs do not always help to exemplify the textual descriptions very well. Drawings would enable more detailed and clear information to be included in the same space.

Some 400 trees are described out of over 2000 species including 35 native species growing in Britain. In general the tree descriptions are concise, clear, most interesting and lacking in botanical jargon, which makes the text easier to read for the non-professional. The glossary is relatively straightforward but would have been improved with the inclusion of a few simple, explanatory diagrams. Within the text emphasis on diagnostic characters relating to each species would also have been useful. In a small number of cases obvious distinctions, such as the different flowering times of the common compared to the Scots laburnum or the upright flowers of the small-leaved lime compared to the pendulous flowers of the common lime, are not mentioned.

Occasional errors, omissions and inconsistencies occur, for example, the misspelling of *Gleditsia triacanthos* at the foot of page 386; there is no reference to *Acer pensylvanicum* nor to contorted hazel and few holly cultivars are mentioned; in the spelling of common tree names, capitals are sometimes used and sometimes not. It must be emphasised, however, that these criticisms are minor. The number of accurate and useful comparisons between the characteristics of similar trees is most impressive. For these comparisons alone it could be argued the book is worth its cost.

John White, one of the authors, was curator at Westonbirt Arboretum. His wife Jill specialised in the education of young children in natural sciences and Dr. S. Max Walters was Director of the Cambridge University Botanic Garden. They therefore bring a wealth of knowledge and understanding to the production of this book and at £25 it represents fine value for money, especially for anyone with more than just a passing interest in trees.

Bob Gray

GUIDE TO GENERA OF CHIRONOMID PUPAL EXUVIAE OCCURRING IN BRITAIN AND IRELAND (INCLUDING COMMON GENERA FROM NORTHERN EUROPE) AND THEIR USE IN LOTIC AND LENTIC FRESH WATERS.

Ronald S. Wilson & Leslie P. Ruse

Freshwater Biological Association, Cumbria, Special Publication No. 13, 2005, 176 pp., soft back with colour photographs and line drawings. ISBN 0-0900386-73-9; ISSN 1747-1958. £20.00

The family of flies called Chironomidae (sometimes rather loosely referred to as non-biting midges) is of great importance in the freshwater environment. Most families of midges do not feed on blood and so it is not a useful way of classifying the many and varied small flies that tend to be prolific around loch-sides, streams and rivers. Those species that annoy humans or spread diseases to us and our stock animals are in the minority. One or two annoying insects can tarnish the image of all. Committed naturalists and other out-door types learn to tolerate the biters in the pursuit of the majority. So what is it about chironomids given they can't bite that make them so important that their transient remains are the subject of a new book?

The Chironomidae form a considerable element of the food chain and so are important to fisheries. They have also become one of the principal means for assessing water quality. After the adult insects have emerged their cast skins remain floating about and can be collected relatively easily. There is also an advantage in not having to kill specimens in order to carry out a survey. The extensive use of chironomids for aquatic monitoring has resulted in a body of knowledge sufficient that such a work as this can be written. Indeed the authors are able to claim that using exuviae is efficient and can be done more easily that sampling other stages of the lifecycle. The keys are of the user-friendly 'Aidgap' style with diagrams showing the character alongside the choice(s) the user is asked to make. There is a most useful summary of the trophic groups of the various genera or species and the kinds of water body preferred. Using this one can relate the species' preferences. A species can be a resident predator of nutrient-poor fast-flowing streams and intolerant of pollution whereas another is a detritus feeder in muddy ponds with a wide range of tolerance to poor oxygen levels, and so on. Consulting this one learns that some few chironomids are terrestrial and one even lives in cow dung. The family is also well-known for containing some of the very few British insects that develop inter-tidally in salt water. Whereas the identification of the cast pupal skins of chironomids is almost entirely an activity for professional biologists or students it is quite gratifying that the means of doing so exists.

E. Geoffrey Hancock

A NEW KEY TO THE FRESHWATER BRYOZOANS OF BRITAIN, IRELAND AND CONTINENTAL EUROPE WITH NOTES ON THEIR ECOLOGY
Timothy S. Wood & Beth Okamura
Freshwater Biological Association, Cumbria, Scientific Publication No. 63, 2005, 113 pp., softback with black & white photographs and line drawings. ISBN 0-0900386-72-X; ISSN 0367-1887, £16.00

The reviewer has attempted to identify freshwater bryozoans on a number of occasions using an earlier production (FBA Publication No.41, 1980). It was not always easy but was no fault of that key. Things move on and now the greater use of modern techniques makes things more certain. The main impetus to more detailed study of these interesting 'moss animals' undoubtedly was the discovery that they are the host to certain fish parasites. These are myxozoans, which are themselves enigmatic animals, whose life cycle in this context had been a mystery. All of a sudden bryozoans have been catapulted into the category of being 'economically important'. Questions need to be answered relating to control and risk. Peering at them through a microscope is no longer an esoteric occupation for the merely curious. Some of the research work on them as vectors of parasites is being carried out in Scotland because of the importance of salmon and trout farms as sources of wealth and employment for local communities. In addition to the issues of identification, so crucial to studying the biology of anything, a considerable part of this booklet is concerned with biology and ecology. It makes interesting reading. The study of freshwater Bryozoa is undergoing some change and more new discoveries and changes will take place. Between the two FBA keys seven species have been added to the British list and two removed. This is an area where scientific investigations are affecting radically the way various creatures' biology are understood at a quite basic level.

E. Geoffrey Hancock

Glasgow Naturalist 2006. Volume 24. Part 4. Pages 165-166.

OBITUARY
William Devigne Russell-Hunter – 1926-2005

Professor W.D. Russell-Hunter, known to his friends as 'Gus', was a long-standing and influential member of The Andersonian Naturalists. He was born in Rutherglen on 3 May, 1926 and died at home in Easton, Maryland in the United States on 21 May, 2005. With his passing, the world has lost one of the most influential freshwater ecologists of the 20th Century.

Gus attended the University of Glasgow and graduated with an Honours BSc in 1946. This degree was followed with a PhD in 1953 and a DSc in 1961, both degrees from the University of Glasgow.

His initial research was in marine biology when, as a result of the Second World War, he served with the British Admiralty as a Scientific Officer on a marine anti-fouling team. This research had been made urgent by the sinking of the fouled – and therefore slower – HMS Hood by the Bismark earlier in the war. His placement on the Scientific and Technical Register, due to his academic achievement, moved him to this duty from his training as a Pilot and Observer flying in Swordfish aircraft (the last cloth and wood biplane to see significant combat in the war). His first published papers in 1948 and 1949 were derived from this work.

In 1948 he was appointed Assistant Lecturer in the Zoology Department of the University of Glasgow, then under the direction of Professor C.M. Yonge. His promotion to Lecturer in 1951 enabled him to achieve the three most important facets of his future life and career. Firstly, he married Myra Porter Rankin Chapman, a talented artist, in the Glasgow University Chapel on March 22, 1951. Secondly, he initiated a series of outstanding courses in invertebrate biology, which the writer was privileged to attend in the late 1950s. Thirdly, he was able to develop a research programme on the physiological ecology of freshwater molluscs in Loch Lomond and other waters in the west of Scotland, which were to prove the basis for his now-classic studies of marine and freshwater organisms and their behaviour, physiological ecology and functional morphology. His field base for these studies was the University Field Station at Rossdhu, which he helped Dr Harry Slack to establish in 1946.

In 1953 and 1954, Gus spent some time in Jamaica as a Carnegie Brown Fellow at the University of the West Indies. His interest in island faunas had been stimulated by his participation in an expedition of young scientists to the Garvellachs – a group of small uninhabited islands off the west coast of Scotland. Useful publications resulted from this trip and, at the time of his death, he was attempting to publish a resulting book, *The Isles of the Sea.*

Dr Russell-Hunter was elected as a Fellow of the Royal Society of Edinburgh in 1965. He was a member of many learned societies during his lifetime, but his oldest membership was with the Natural History Society of Glasgow, which he joined when it was still the Andersonian Naturalists of Glasgow. He became an influential member of the Andersonians when he was elected to Council and also became Editor of *The Glasgow Naturalist*. During his time as Editor he maintained a high standard of editing and attracted many important papers to the journal. At the time of his death, he was the member of longest standing in the Society, having joined in November 1948.

From 1961 to 1963, though still based at the University of Glasgow, Gus visited the Marine Biological Laboratory at Woods Hole, Massachusetts, where he served as a summer lecturer in the influential invertebrate zoology course. Scotland's loss was the United States' gain when he moved to a permanent appointment there as director of that course from 1964 to 1968. His experience with *The Glasgow Naturalist* proved of value when he served as Editor of the laboratory's *Biological Bulletin* from 1968-80. During those years this journal rose to prominence as a leading biological journal. Gus was also appointed to the Board of Trustees of the Marine Biological Laboratory, on which he served for four terms and in *emeritus* status thereafter.

As well as his appointment at Woods Hole, Gus was appointed to the staff of the Biology Department at Syracuse University, where he taught from 1963 to 1990. His career there, in both teaching and research, was distinguished and he and his many graduate students not only produced significant research but also created an environment for learning about biology for which the university became well known. He received research grants from many bodies and was recognised by the University in 1988, who honoured his teaching career with the William Wasserstrom Award.

In spite of being very busy with teaching and research, Gus managed to write four major texts – *A Biology of Lower Invertebrates* (1968), *A Biology of Higher Invertebrates* (1969), *Aquatic Productivity* (1970) and *A Life of Invertebrates* (1979). All of these were foundational for decades of students of invertebrate zoology throughout the world in their various translations.

Over his long research career of nearly six decades, Gus authored and published over 120 research papers. He was involved in very many more than this through his research students, but chose not to follow the common practice of adding his name so as to allow them a better chance to launch their own careers. This facet of his life – that of mentor and teacher – was perhaps his greatest hall mark as his generous and gracious work advising his graduate and undergraduate students created a culture of researchers and teachers through whom he has had a global impact in the fields of physiological ecology, malacology and invertebrate zoology.

His long career was honoured in 1984 at the 'International Symposium on the Physiological Ecology of Freshwater Molluscs Honoring Dr. W.D. Russell-Hunter', the 50th Annual Meeting of the American Malacological Union. At this symposium, a full account of his extensive scientific achievements was presented in a paper by McMahon & Burky (1985: *American Malacological Bulletin*, 3, 135-142). He was again honoured in 1999, when the Freshwater Mollusc Conservation Society presented him with their first-ever Lifetime Achievement Award.

In later years, after the death of his wife, for whom he cared during her decade-long battle with cancer, Gus turned to oil and acrylic painting (for which he won awards), boating, reading and the Religious Society of Friends. A memorial service was held for him at the Marine Biological Laboratory and his ashes were scattered in the waters near Martha's Vineyard where he had loved to sail with Myra during summers at Wood Hole.

He is survived by his son Peregrine and three grandchildren.

Peter S Maitland

A similar obituary notice appeared in the Woods Hole Marine Laboratory Web Site.
http://www.mbl.edu/ Then seach for obituaries. Thursday 28th December 2006.

Proceedings 2005

The Chairman, place, lecturer's name and title of lecture are given for most meetings.
GKB - Graham Kerr Building; ; WILT-Western Infirmary Lecture Theatre

11th January
Roger Downie, GKB,24,, Paisley International Colour Slide Exhibition. Compiled by members of Paisley Photographic Club, presented by Winifred Brown and projected by Jim Campbell.

1st February
Roger Downie, GKB, 37. "Adventures in the wilds of N. America with the world's best studied songbird" Glen Chilton.

22nd February
Roger Downie, GKB, 75th AGM. 38. Reports were given about activities during 2004 and elections were held. Membership stood at 272 made up of 189 ordinary, 41 concessions, 39 family, 5 honorary and 3 school members. There were 3 council meetings and 3 BLB meetings held during the previous year.
The AGM was followed by Roy Sexton talking "The secret lives of our Native Orchids"

8th March
John Knowler, GKB, 36,Prof. Jim Dickson and Petra Mudie ".The Life and Death of Kwaday Dan Ts'inchi Long ago person found."

6th April
John Knowler, GKB, 30, Members Photographic Night

10th May
Bob Gray, GKB,Presidential address by Dr Roger Downie "In cold blood – tales of a herpetologist"

8th June
Summer Social to Greenbank Gardens followed by a meal in Giotto's restaurant in Clarkston

Excursions
21 excursions took place throughout the year.

20th September
GKB, Exhibition meeting with wine and cheese.

11th October
John Knowler, GKB, Jacqui Kaye BTO "Birds in your Garden. Preceded by tutorial by John Simpson –Bean Geese.

8th November
John Knowler , GKB, , Richard Sutcliffe "The New Natural History Displays in Kelvingrove" Preceded by Richard Weddle on Conservation of the Great Yellow Bumble Bee.

30th November
John Knowler ,Western Infirmary Lecture Theatre. Fifth BLB Lecture. "Cuckoos versus hosts; an evolutionary arms race", speaker Prof Nick Davies.

13th December
Glasgow University Club. Christmas Dinner.
June McKay gave a illustrated talk on "Botanising in Sichuan"

Officers and Council elected at the 2005 AGM

President:
Prof John Knowler

Vice Presidents:
Robert Gray, BSc.,MIBiol.
Prof. Norman R. Grist, , BSc, MB, ChB, FRCP, FRCPath.
Roger Downie, BSc, PhD.

Councillors:
Ian McCallum, CEng, MICE , FIHT
Janet Palmar, BSc, PhD.
Edna Stewart, BSc.
Ruth Dobson, BSc, MSc.
Tracy Livingstone

General Secretary:
Mary Child, BSc

Assistant Secretaries.
Fiona Giffard, BSc. (Meeting Minutes)
Edna Stewart, BSc. (Minute Book)
Dominic McCafferty (Publicity)
Hazel Rodway (Social)

Treasurer:
Morag Mackinnon, BA, BSc

Membership Secretary:
Richard Weddle, BSc .

Librarian:
Janet Palmar BSc, PhD

Editor:
Dominic McCafferty

Newsletter Editor:
David Palmar.

Section Convenors
Keith Watson, BSc, MSc. (Botany)
Richard Weddle, BSc. (Bio-recording)
Joyce Alexander (Excursions)
Julian Jocelyn (Geology)
Sandy McNeil (Ornithology & Photography)
Geoff Hancock, BSc, FMA. (Zoology)

BLB Scientific Advisor
Peter Macpherson FRCP, FRCR, DTDC, FLS.

THE GLASGOW NATURALIST: Advice to Contributors

1. The Glasgow Naturalist publishes articles, short notes and book reviews. Book reviews are commissioned by Bob Gray. Books reviewed are kept in the Society's Library. Articles and short notes should be sent to the current **Editor from Volume 25 part 1 onwards: Dominic McCafferty, DACE, St Andrews Building, University of Glasgow, 11 Eldon Street, G3 6NH, Scotland (Email: D.McCafferty@educ.gla.ac.uk).**
Articles and short notes are refereed. Acceptance of articles and short notes is the responsibility of the Editor. The journal is published yearly. The subject matter of articles and short notes should concern the Natural History of Scotland in all its aspects, including historical treatments of natural historians.
2. Short notes should not normally exceed one page of A4 single-spaced. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new stations for a species, rediscoveries of old records, additions to records in the Atlas of the British Flora, unusual dates of flowering, unusual colour forms, ringed birds recovered, weather notes, occurrences known to be rare, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.
3. Articles should be more substantial than short notes. The maximum length should not exceed approx 6000 words including references and equivalent space for tables and references. Longer articles should be discussed with the Editor before submission. They should be headed by the title and author's name and address. Any references cited should be listed in alphabetical order under the heading References. The text should be divided into sections with sub-headings as appropriate.
(e.g. Abstract, Introduction, Methods, Results, Discussion, Conclusions, Acknowledgements, References)
4. References in articles and short notes should be given in full (please do not abbreviate journal titles) according to the following style:
Pennie, I.D. 1951. Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.
Wheeler, A. 1975. *Fishes of the World.* Ferndale Editions, London.
Grist N.R. & Bell, E.J 1996. Enteroviruses. Pp. 381-90 in Weatherall, D.J. (editor) *Oxford Textbook of Medicine.* Oxford University Press, Oxford.
5. Nomenclature of vascular plants should be as in Stace, C.A. (1997). *The new Flora of the British Isles*, (Second Edition) Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply.
Please use lower case initial letters for all common names e.g. wood avens; blackbird, unless the common name includes a normally capitalised proper name e.g. Kemp's ridley.
Where giving distribution information by vice-county, use the following style: VC 30.
6. Submitted manuscripts (two copies) should be typed double-spaced on A4 paper. Typesetting is greatly assisted if the manuscript can be supplied on a microcomputer diskette. Authors are therefore strongly encouraged to produce manuscripts using a word processor (preferably on a PC-compatible microcomputer). However, to assist amateur naturalists, the Editor can make arrangements to have hand-written manuscripts or typed manuscripts transferred to disc.
7. Tables are numbered in Arabic numerals e.g. Table 1: they should be double-spaced on separate sheets with a title and short explanatory paragraph underneath.
8. Figures, Line drawings and photographs are numbered in sequence in Arabic numerals e.g. Fig. 1. If an illustration has more than one part, each should be identified as 9 (a), (b) etc. The orientation of the figure and name of the first author should be indicated on the back. They should be supplied camera-ready for uniform reduction of one-half on A4 size paper. Line drawings should be drawn and fully labelled in Indian ink or dry-print lettering or laser printed. A metric scale must be inserted in micrographs etc. Legends for illustrations should be typed on a separate sheet. The Editor is able to accept a small number of high quality colour photographs for each issue. Please consult the editor before submitting the paper.
9. Proofs should be returned to the Editor by return of post. Alterations should be kept to the correction of errors. More extensive alterations may be charged to the author.
10. Offprints.Ten offprints and one complimentary copy of the Journal are provided free of charge. Further copies may be purchased, provided that they are ordered at the time the proofs are returned.
11. Review. The Editor or his appointed referees review all submissions. The Editor for ethical considerations also assesses them. Publication may be refused on the recommendation of the editorial committee.